A METHOD TO PREDICT THE STATICAL STABILITY OF MERCHANT SHIPS IN PRELIMINARY DESIGN

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A METHOD TO PREDICT THE STATICAL STABILITY OF MERCHANT SHIPS IN PRELIMINARY DESIGN

by

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Submitted in Partial Fulfillment
of the Requirements for the
Degree of Naval Engineer

from the

Massachusetts Institute of Technology

1956

Cambridge, Massachusetts
21 May 1956

Professor Leicester F. Hamilton,
Secretary of the Faculty,
Massachusetts Institute of Technology,
Cambridge, Massachusetts.

Dear Sir:

In accordance with the requirements for the degree of Naval Engineer, we submit herewith a thesis entitled: "A Method to Predict the Statical Stability of Merchant Ships in Preliminary Design."

Respectfully,

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Thesis
J53

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ABSTRACT

Title of Thesis: A Method to Predict the Statical Stability of Merchant Ships in Preliminary Design.

Names of Authors: Alberto Jimenez
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Submitted for the degree of Naval Engineer in the Department of Naval Architecture on May 21, 1956.

The authors have developed curves of KZ/B which may be entered with C_B, B/H and H/D to predict the curve of statical stability for merchant ships of normal form. Due to lack of time a correction for the effects of superstructure and variations in shear and flare has not been developed. Such a correction should be introduced before the results are used. It is felt that good agreement will then be obtained, and evidence to substantiate this expectation is furnished from previous work on the subject (Ref. 39).

The main difference between our work and that of previous investigators is the use of series 60 parent with standard shear and normal flare, the abandonment of methods of longitudinal expansion of the generated data, and a refinement of the method of lateral expansion.

The feeling is expressed that the parent form method has been carried to the limit of what can be accomplished on a 20-hour thesis by the use of integrator methods, and the use of a digital computer in future investigations is suggested. A program for such a computer solution is available (Ref. 24). Recommendation of a thorough investigation of the precision of measurements and calculations along the lines suggested by Ref. 13 is also made.

Considerable stability data which may be found useful is included. The cross-curves of stability for eight merchant ships, as well as the integrated data for our parents, which may be considered typical series 60 ships, is presented in the Appendices.

Thesis Supervisor: George C. Manning

Title: Professor of Naval Architecture

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LIST OF SYMBOLS

L - Length

B - Beam

D - Depth

H - Draft

$\triangle$ - Displacement or volume of displacement

C_b - Block coefficient

C_p - Longitudinal prismatic coefficient

C_v - Vertical prismatic coefficient

C_w - Waterplane coefficient

C_x - Midship section coefficient

G - The position of the center of gravity of a ship, actual or assumed

K - The intersection of a ship's centerline with the baseline

KG - The distance between K and G measured on the centerline of the ship

Z - The intersection of the line of action of the force of buoyancy with a horizontal line through K

B - The position of the center of buoyancy of the ship

ZB - The distance from Z to B measured on the line of action of the force of buoyancy

KZ - The distance from K to Z measured horizontally, the stability arm

LIST OF SYMBOLS (cont.)

GZ - The righting arm, the horizontal distance between the lines of action of the forces of gravity and buoyancy

θ - The angle of inclination of a vessel in degrees

B/H - Beam - draft ratio

H/D - Draft - depth ratio

B/D - Beam - depth ratio

KZ/B- Stability arm - beam ratio

WL - Waterline

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I. INTRODUCTION

In the early stages of design, before the lines of a ship are drawn, the standard procedure for determining the curve of statical stability can not be used. Methods for drawing an approximate curve by proportioning from similar ships are described in the literature, but they are based on the estimation of a very few points and their accuracy is limited.

It would be highly desirable if curves could be developed which were entered with the principal dimensions and coefficients of form, and which would give directly the values of the righting arm at the various angles of inclination. Considerable work has been done on this subject. In this work, two main trends are discernible: (1) analytical methods and (2) methods based on parent forms. Although the desired product is the same, the methods are so different that they will be discussed separately.

ANALYTICAL METHODS: In 1920, Dr. Shultz published in "Schiffbau," a formula that gave the righting arm in terms of the angle of inclination for "normal" ships. Eighteen years later, Aleman (Ref. 25) applied this formula to several merchant ships and found fairly good agreement for ships floating near the designer's load waterline. Gunney and Unel (Ref. 31), in 1944, although realizing that naval ships were hardly of the "normal" form to which Dr. Schultz referred, confirmed that the formula did not work for ships of this type. A formula with

essentially the same limitations as that of Dr. Schultz was published in 1932 by Niedermair (Ref. 14). It gives good results for ships of "normal" form up to the angle of deck edge immersion. Burgess (Ref. 12) published a method in 1943 based on a comparison between the shift of the center of buoyancy in a prism with that in a ship form; the method is somewhat long, but has the advantage of being applicable to a wide variety of ships. In 1947, Prohaska (Ref. 16) introduced the concept of residuary stability. This procedure evoked considerable interest, but its principal disadvantage lies in the requirement of the estimate of the location of the center of gravity early in the calculations. In the early stages of design, this just means an additional source of inaccuracy and a lengthy calculation for every change in the initial estimate of the value of KG. An entirely new approach, utilizing harmonic analysis was developed in 1948 by Bernhart and Thewlis (Ref. 26). It gave good results for a wide variety of ship forms, but the calculation is lengthy for use in preliminary design.

PARENT FORM METHODS: Several decades ago, Admiral Taylor demonstrated that in problems which defy analytical treatment by their complexity, an excellent way to obtain and present useful data is to choose a prototype "parent ship," to expand this parent by systematic variation of the elements of form to cover the desired range of shapes, and to then plot the desired data (obtained experimentally) for this series of ships. Values for any particular ship can be obtained by interpolation from

the published data. It was logical that something similar be tried to solve the statical stability problem. Instead of experiments, actual computation of the curves of statical stability for the various ships of the series were carried out by the standard methods.

The first work along these lines was that of Ramsay and Latimer (Ref. 36) in 1945. They considered three parent forms. Each had the same profile (including shear), but their underbodies had rectangular, triangular, and elliptical cross-sections. Although the general shape of the curves which they obtained was correct, they had errors of up to 25% in the values of maximum righting arm. The most that they could claim for their curves was that they would be useful for determining the effect on stability for small changes in form. In view of these poor results, the following year, Kelley, Jones, Crawford, and Gooding (Ref. 33) switched to hulls delineated from Taylor's Mathematical Lines, and they completed two hulls keeping C_p constant while varying C_b. In the same year, McKay (Ref. 35) obtained cross curves by varying H/D. In 1948, Randall, Stark, and Meyer (Ref. 37) continued the work of Kelley, et al, by making the computations for six more hulls based on Taylor's Mathematical Lines. In each of the six parents, only C_p, C_b, or C_w varied from the original. Their results, however, showed errors of up to 15%. In the same year, Taylor, Ballantine, and Rietz (Ref. 38) arrived at the conclusion that previous inconsistencies were due in fact to the various hull forms used in that they were

not truly related, and they worked on six new Taylor's Mathematical Lines hulls characterized by a uniform variation of the hull coefficients. Their work was continued in 1949 by Church and Robinson (Ref. 28) who arrived at the conclusion that the Rietz parameter (C_w^3/C_b) was not acceptable for plotting stability data. Furthermore, they decided to start a new series based on Taylor Standard Series hulls with only one parameter changed at a time, and made use of a method for expanding the stability data laterally, thus saving considerable calculation time. In 1951, Hubbard and Thompson (Ref. 39) made a careful analysis of the relevant parameters and finally decided that good curves would be obtained by plotting KZ/B for systematically varied values of D/B, H/D, and C_p, plus a correction for shear. In the same year, McCandliss (Ref. 34), while working independently, produced comparative plots of stability data based on several different sets of parameters, including the factor KZ/B. The use of KZ/B instead of GZ/B by both Church and Robinson and by McCandliss represents a considerable improvement because it eliminates the necessity of repeating the entire calculation for each estimated value of KG. Hubbard and Thompson, by using the method of Church and Robinson for lateral expansion, obtained data for 12 hulls. Their final curves gave good results when applied to 3 cargo ships. However, good agreement could not be obtained for tanker forms. They gave as a possible reason for the lack of agreement, certain inaccuracies in the method of lateral expansion that they used. In 1952, Brown, Fargo,

and Fick (Ref. 27) decided to apply a similar method to warships and developed a Warship Standard Series based on cruiser hulls. They were able to obtain good agreement for certain types of warships, but not for others.

After an exhaustive study of the work of all these previous investigators, the present writers decided that the parent form method was the most promising, and that the application of this method to merchant ship forms had been progressively improved in succeeding theses. Hubbard and Thompson's work gives the best results in the prediction of stability curves for actual merchant ships, It was therefore agreed that we would make a thorough analysis of the ideas and methods of this thesis, and start our work from there.

The discussion of the important parameters given by these authors, as well as their selection of the necessarily limited number that would be taken into consideration in the stability study, was found excellent, and no attempt was made to improve on it. Analysis of their procedure, however, led us to the conclusion that the most likely source of inaccuracy was in connection with the longitudinal expansion, and that to remedy the discrepancies would require a more involved method of expansion, which would entail as much work as integrating each hull independently. The lateral expansion method was also found to contain inaccuracies, but these were due to only one specific step and could be easily remedied by doing that one step in more elaborate fashion. A detailed discussion of

these points is given in Appendices A and B.

Since 1951, when Hubbard and Thompson did their work, the long-felt need of a new set of standard lines representative of modern merchant practice to replace the Taylor standard series has culminated in the development of Series 60 (Refs.20, 21, and 22). Since our main objective is to predict the stability curves of modern merchant ships, and the effect of form on stability is so marked, it was deemed advisable to abandon the Taylor standard series parents entirely and to use Series 60 parents in our work. Besides, it was felt that any contribution to the growing fund of data on Series 60 would be useful to the profession, especially since no work on the stability of this series had been done.

As is well known, Series 60 has abandoned Taylor's method of longitudinal expansion to vary C_p because it leads to unrealistic ship forms. Instead, Series 60 has one parent for each of the basic C_b values (0.60, 0.65, 0.70, 0.75, and 0.80). This is no great loss for our work, since we had already decided, for the reasons given above, not to use the method of longitudinal expansion in the generation of stability data for various C_b coefficients.

In keeping with the idea of generating data from parents representative of actual merchant ship form, it was decided to abandon Hubbard and Thompson's idea of generating stability data up to an arbitrary "flat top" which required the introduction of a fictitious depth in order to account for shear and flare. It was considered much more realistic to actually draw body

plans which retained exactly the form of the Series 60 hull, but which also included shear and flare representative of modern merchant ship practice. Standard Load Line Shear was adopted and medium flare was taken from the values adopted by panel H-7 of the Society of Naval Architects and Marine Engineers for its seakeeping experiments on Series 60 hulls.

To determine the applicable range of ratios and coefficients, a tabulation of these values taken from actual ships was made (see Appendix C). From this table, the following average ratios were derived:

Ship Type	L/D	D/B	H/D	L/B	B/H
Tankers	13.8	0.54	0.76	7.4	2.4
Full Scantling Cargo Ships	11.5	0.62	0.74	7.2	2.2
Shelterdeckers	11.3	0.62	0.67	7.0	2.4

In this table, L refers to the length between perpendiculars, and D to the depth up to the main deck in the case of full scantling ships and up to the shelter deck in the case of shelterdeckers.

In the light of these results, and because the range of C_b covered by series 60 includes all usual merchant ships, it was decided to generate data for the following range of parameters:

C_b	0.60 to 0.80
B/H	2.00 to 3.00
H/D	0.60 to 0.80

As can be seen, we use B/H and H/D instead of D/B and H/D, as did Hubbard and Thompson. This is not really a fundamental difference, and was adopted because Series 60 uses B/H as a defining parameter. Exactly the same can be said of our use of C_b instead of C_p. The use of KZ/B as the final parameter to present the results has been retained.

II. PROCEDURE

Once the decisions mentioned in the INTRODUCTION were made, we proceeded to draw body plans of the series 60 parents corresponding to C_b of .60 and .80. A body plan of suitable scale was available for the C_b .70 parent from work which Professor Manning had done in England. Body plans for the intermediate parents of C_b .65 and .75 were not drawn because of time limitations. Further, it was felt that these three would define the variation of stability with C_b well enough for interpolation. The dimensions, scale, shear, and flare adopted for the parents is discussed in Appendix B. The body plans were checked by comparing areas at various stations up to the load waterline with those given in reference(21).

Each parent was then integrated for volume and center of buoyancy following the standard integrator method. Each body plan was integrated at 0, 10, 20, 30, 45, 60, 75, and 90 degrees; at each of these angles the integration was carried up to five different waterlines. Grids containing the waterlines were made on tracing paper and placed over the body plans at the desired angle. The grid was always rotated about the intersection of the centerline and the baseline, point K. The method of slices was used, that is the hull was integrated up to the lowest waterline at any given angle, for higher waterlines the portion between the desired waterline and the next lower waterline was integrated and the

result added to the previous total. The waterlines chosen depended on the angle of heel. At high angles the waterlines must be more widely spaced to maintain the same spread of displacement as at the lower angles. As explained in Ref. 7, this insures that the cross curves are well determined over the desired range of displacement for all angles.

A standard form was prepared to tabulate the data, a sample of which is given in Appendix D, Table X. All integrations were done in the clockwise direction so that the area dial readings always increased, while the moment dial readings decreased for positive moments (i.e. the side away from the integrator track was taken as positive) and increased for negative moments. The axis of moments was made to pass through K whenever possible; when the integrator would not reach all parts of the body plan, the axis was displaced so that KG $\sin\theta$ equaled 1". The constants of the integrators used were carefully determined by going around known areas of different sizes and shapes and taking a statistical average. These are given in Appendix B. All these precautions and the standardization of the procedure paid dividends in the compatibility of the data generated by different members of the team and in the ease with which any of the data could be checked.

The above integration gives the value of KZ, and is all that is normally done. In order to use the method of lateral expansion, the location of the center of buoyancy must be

completely defined. KZ gives its coordinate in the horizontal direction. Hubbard and Thompson determined the vertical coordinate by the standard method of integrating a curve of displacement vs. draft and dividing by the displacement. As discussed in Appendix B, this method presents several difficulties when a high degree of accuracy is desired. Therefore, we did not use it. Instead, we repeated the integration process described above for the determination of KZ (at the same angles and waterlines) but with the axis of the integrator rotated 90 degrees, thus determining ZB. ZB is the vertical distance from a horizontal line through K to the center of buoyancy. (See Figure I.) This method does not require more work than Hubbard and Thompson's procedure if the latter is carried to the needed degree of accuracy. Our method has the advantage of providing a check on the integrated values of displacement.

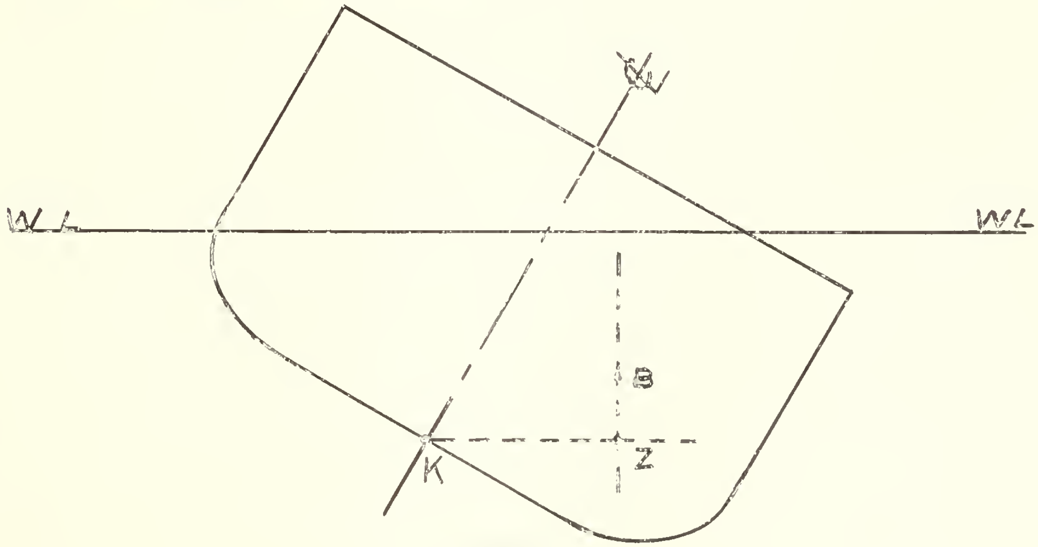

FIGURE I

Once the location of the center of buoyancy of the three parents was determined, the method of lateral expansion, described in detail in Appendix B, was used to predict values of KZ for the offsprings. This meant going from a B/H of 2.32 (value for the parents) to B/H of 2.00, 2.50, 2.75 and 3.00. As mentioned before, this covers the range of usual merchant ships. It should be pointed out, however, that in a recently published paper (Ref. 22) the plan of experimentation on series 60 has been changed to cover the range 2.50 to 3.50, instead of 2.00 to 3.00 as originally planned, because of the modern tendency to higher B/H ratios. If in the future, the data given in this thesis needs to be expanded above the 3.00 limit, this can be easily done by plotting additional points, using the same procedure of lateral expansion for the desired values of the ratio B/H.

For purposes of identification, each hull was assigned a number as follows:

TABLE II

		B/H 2.00	B/H 2.32	B/H 2.50	B/H 2.75	B/H 3.00
C_b	0.60	14	11	13	15	12
C_b	0.70	34	31	33	35	32
C_b	0.80	54	51	53	55	52

From the data obtained by integration, plus the data generated by the lateral expansion, it was possible to plot cross-curves of stability (KZ vs. displacement) for each of the 15 hulls. The cross-curves of the three parents, hulls

11, 31, and 51, are given as figures XXIV, XXV, XXVI, in Appendix F. The cross-curves for the other twelve hulls are for odd angles that result from the lateral expansion. Time did not permit us to reduce these curves to standard angles. Therefore, they were not published.

The next step is to read from the cross-curves the value of KZ for each hull at each angle for displacements corresponding to various H/D ratios. The ratios selected were H/D of .60, .65, .70, .75, and .80. These values as can be seen from Table IV, Appendix C, cover the range of H/D values encountered in merchant ships. These H/D ratios refer to the load waterline.

Curves of stability arm (KZ) vs. angle of heel were drawn for each hull at the same H/D ratio. These were plotted as families to show the variation in KZ with B/H at constant values of H/D and C_b. These are figures XXVII through XLI in Appendix F.

In plotting these curves it was found that unfairness was difficult to detect. The method of plotting righting arm (GZ) vs. angle of heel was used to check the fairness. A value of KG = 3" was used with all hulls. Unfairness in the GZ vs θ-curves was easily detected. Fairing was accomplished by this method. The need for such fairing, we think, is unavoidable in processes of mechanical integration, computation, and graphical expansion such as were followed in this work. Fairing was negligible in the integrated data for hulls

11 and 51, but some was required for hull 31. The offspring, in general, showed scattering at low angles of heel. This is to be expected from an analysis of the graphical lateral expansion process. (See Appendix B.) The scattering was small and of the magnitude that is reasonable to expect from the generated data.

Our next step was to try various ways of plotting the generated data to find the one easiest to use to predict the statical stability curve of a ship. We tried plots of KZ/B vs. H/D at constant B/H and C_b. Also, the superposition of families of H/D and C_b were tried. KZ/B vs. C_b at constant B/H and H/D was tried with and without superposition of families. Our choice is KZ/B vs. B/H at constant H/D and C_b for each angle plotted in families of H/D. These are given as figures II through X in Section III, Results.

Curves of displacement vs. draft in the upright condition are given as figure XLII, in Appendix F.

III. RESULTS

Figures II to X constitute the final presentation of our data, and have been prepared with ease of use in mind. The desired parameter, **KZ/B**, is plotted as ordinate to a very large scale, so that visual interpolation may be used without loss of accuracy; as will be pointed out in the next section, very small variations in this value produce considerable variation in GZ values, so accuracy is paramount. The abscissa is B/H, and for each angle a range of H/D is covered. There is a complete set of curves (angles every 10° up to 90°) for each C_b, the C_b interpolation being the only one that can not be done directly in the graph. Previous trial plots with C_b as the abscissa showed that in the range covered the variation of KZ/B with C_b was essentially linear, so that once the values of KZ/B are read for each of the C_b's within which the desired value lies, linear interpolation can be used to determine the values for the ship in question.

This method of prediction has been applied to eight merchant ships for which cross-curves of stability were available. Despite our efforts, these were all the cross-curves that we were able to obtain. Figures XI and XII show the curve of statical stability of each of these ships at their designer's load draft. The solid line has been obtained from the cross-curves; the dotted line is the curve predicted by the method

described above, and the dash-dot line the curve predicted by the method of Hubbard and Thompson, ref.(39). The general characteristics of the eight ships and their cross-curves have been included in Appendix C, as they may be useful to those desiring to check our calculations or to obtain curves at other displacements. The actual calculation of the predicted points, by both methods of prediction, may be found in Appendix C.

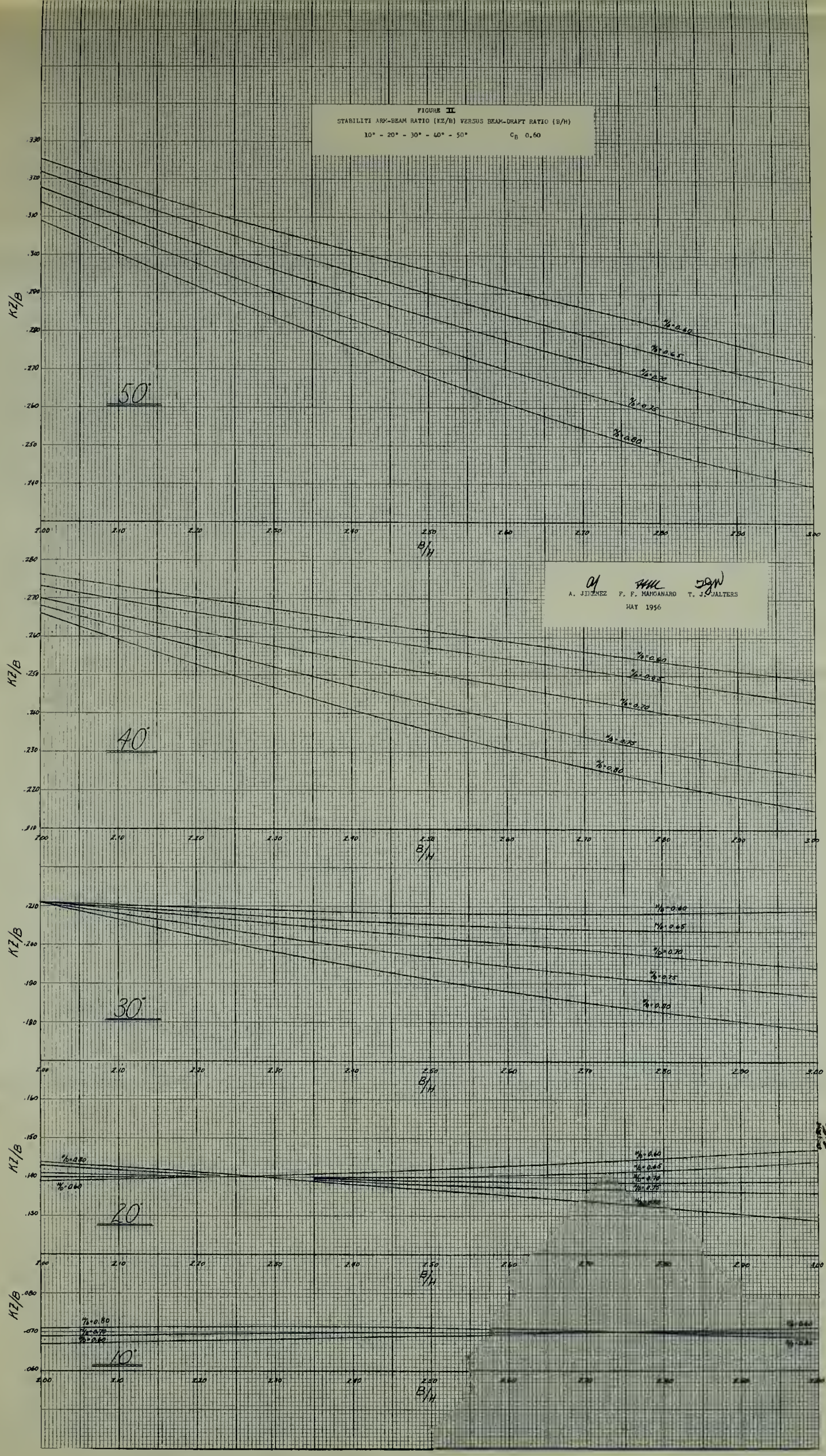

FIGURE II

STABILITY ARM-BEAM RATIO (KZ/B) VERSUS BEAM-DRAFT RATIO (B/H)

10° - 20° - 30° - 40° - 50° C_B 0.60

AJ FFM TJW

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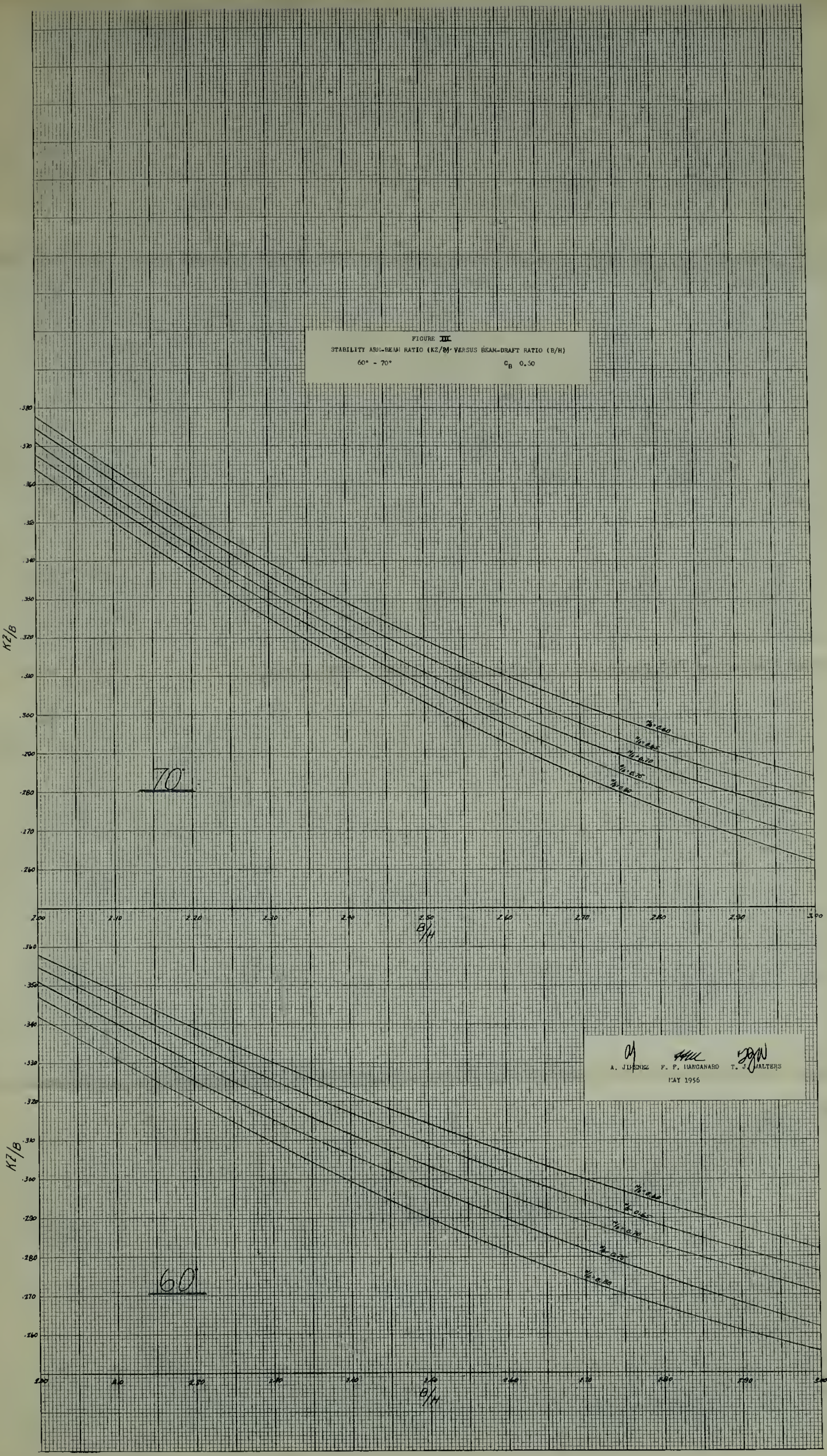

FIGURE III

STABILITY ARM-BEAM RATIO (KZ/B) VERSUS BEAM-DRAFT RATIO (B/H)

60° - 70° C_B 0.50

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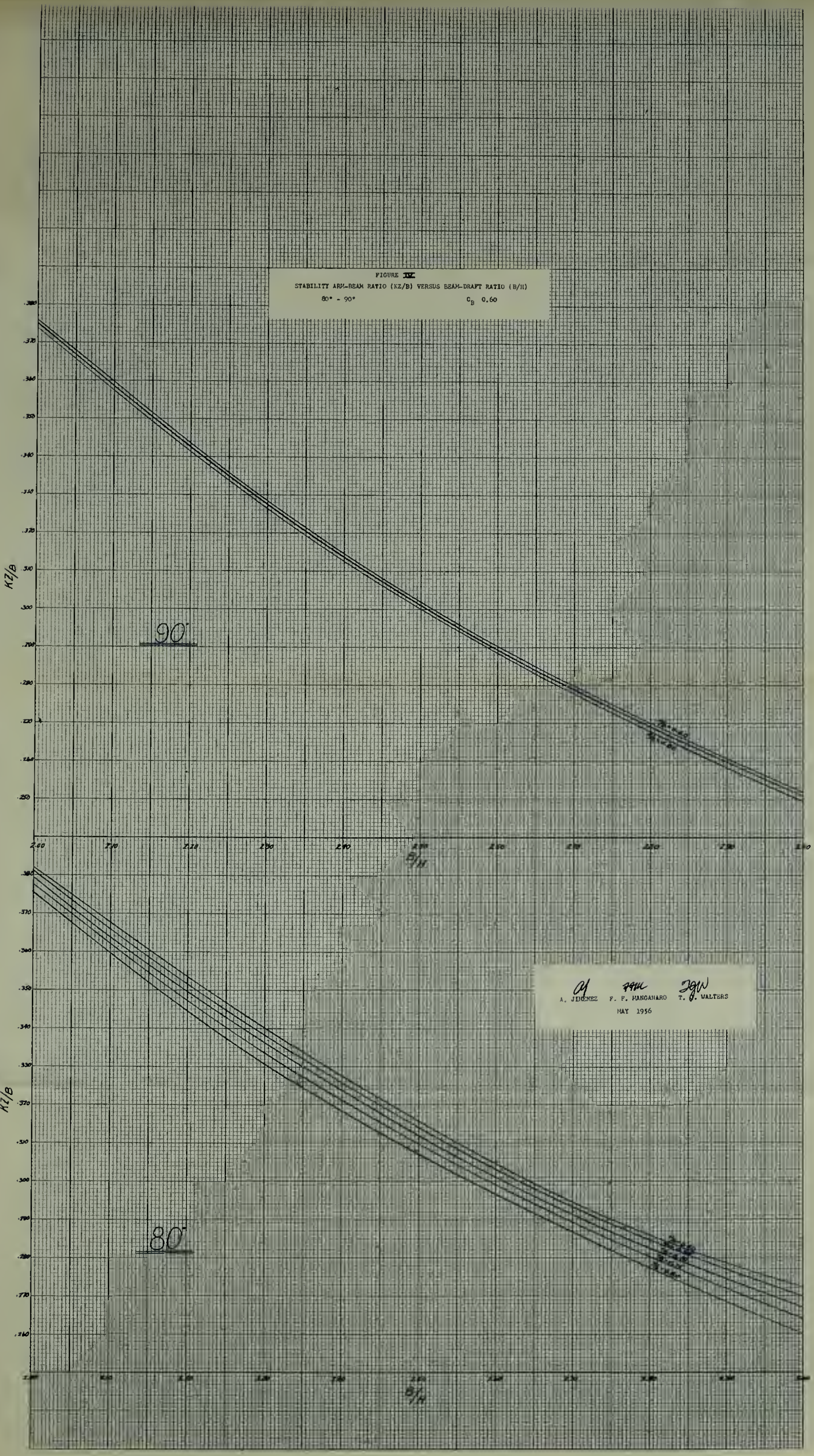

FIGURE IV

STABILITY ARM-BEAM RATIO (KZ/B) VERSUS BEAM-DRAFT RATIO (B/H)

80° - 90° C_B 0.60

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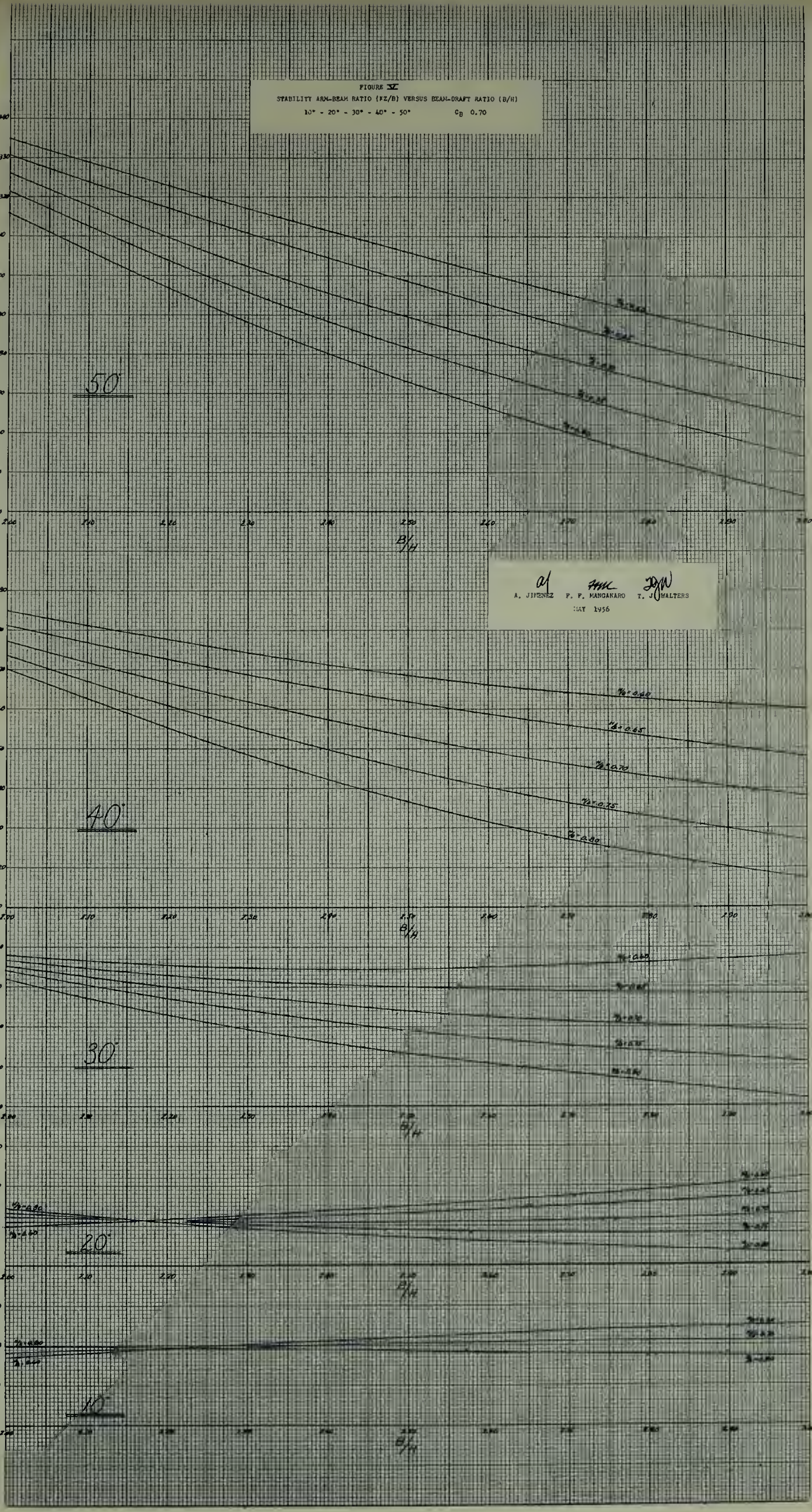


FIGURE V

STABILITY ARM-BEAM RATIO (KZ/B) VERSUS BEAM-DRAFT RATIO (B/H)

10° - 20° - 30° - 40° - 50° C_B 0.70

A. JIMENEZ   F. F. MANGANARO   T. J. WALTERS

MAY 1956

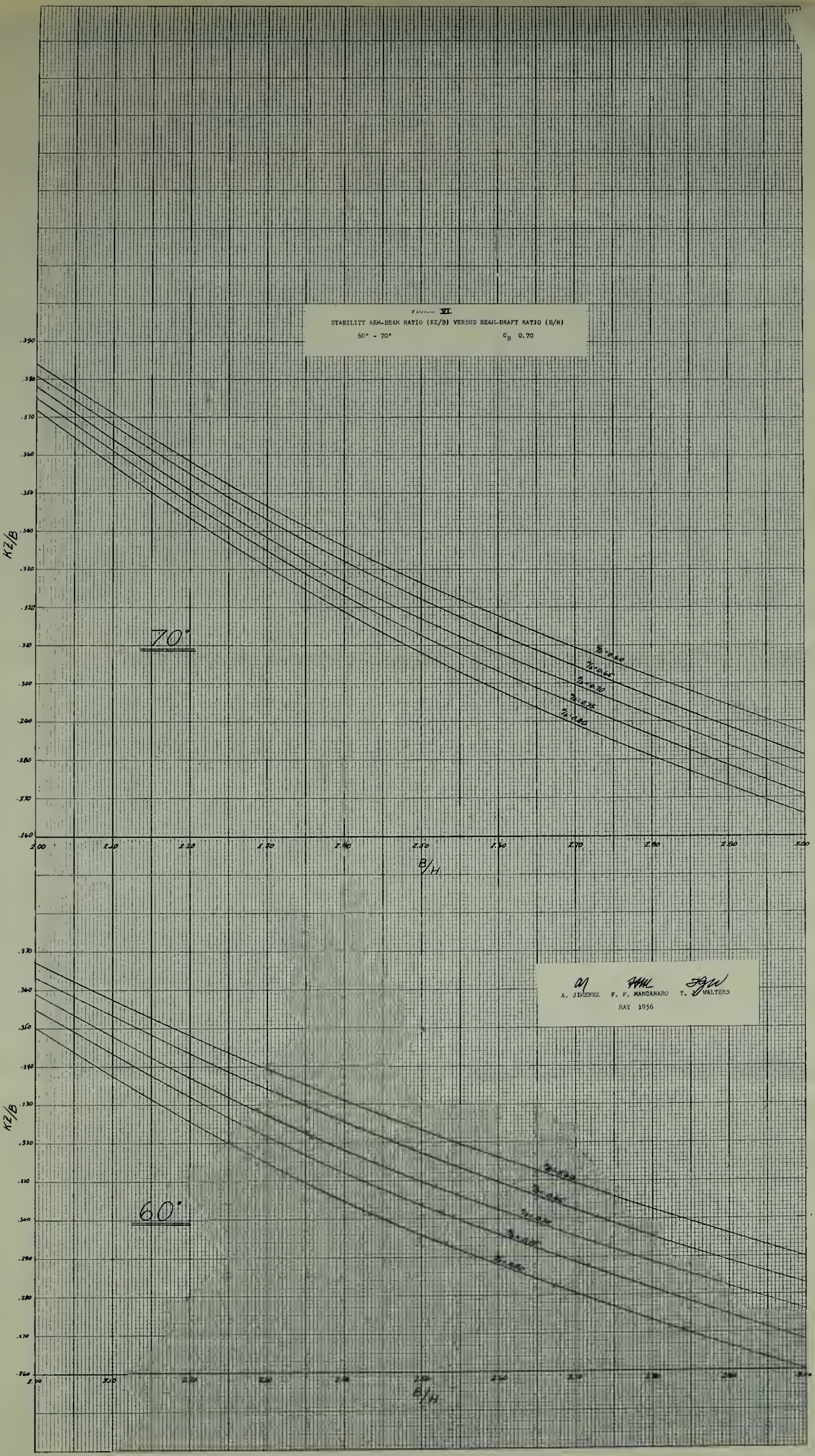


FIGURE VI

STABILITY ARM-BEAM RATIO (KZ/B) VERSUS BEAM-DRAFT RATIO (B/H)

60° - 70° C_B 0.70

A. JIMENEZ F. F. MANGANARO T. J. WALTERS

MAY 1956

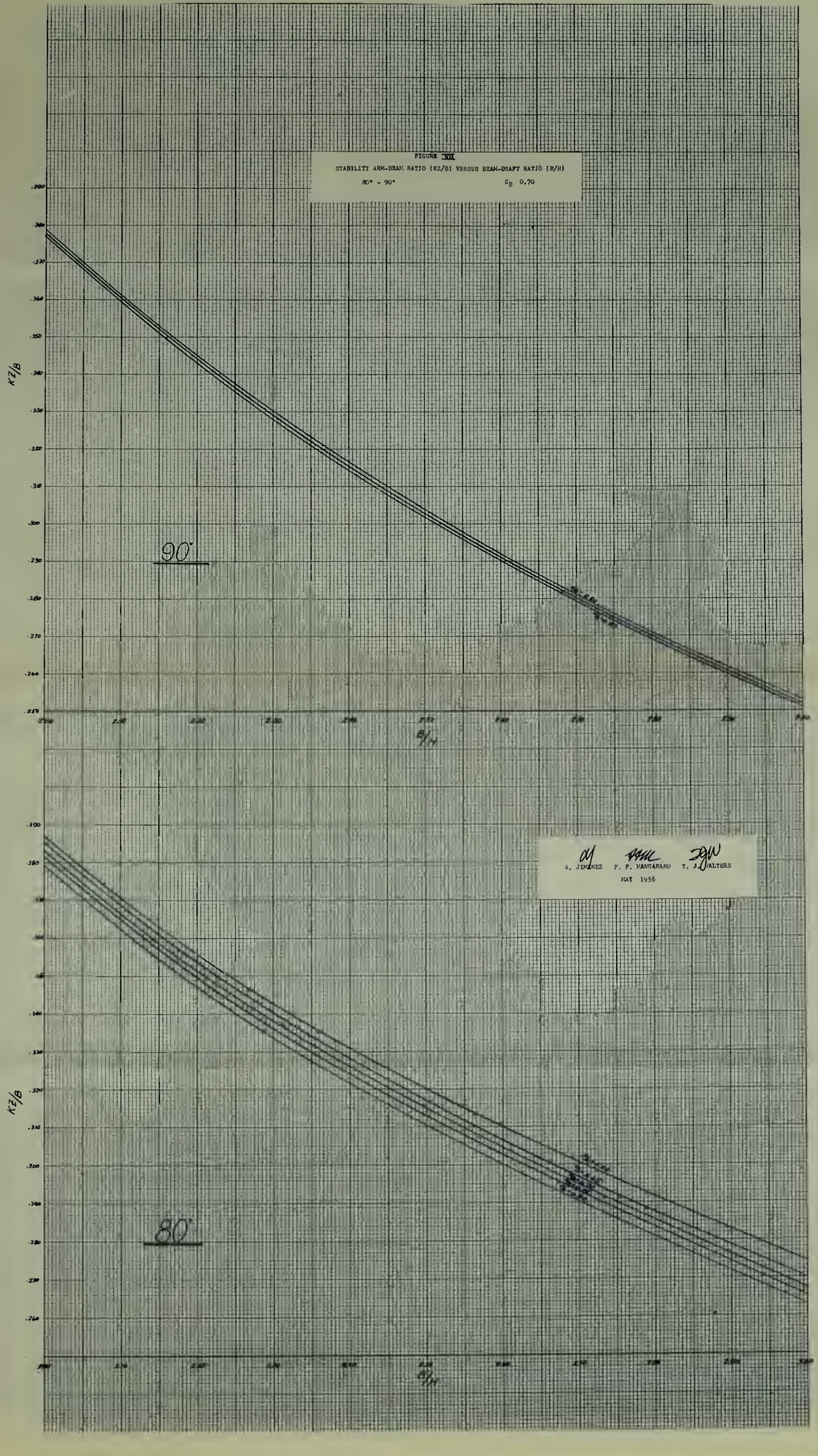


FIGURE VII

STABILITY ARM-BEAM RATIO (KZ/B) VERSUS BEAM-DRAFT RATIO (B/H)

80° - 90° C_B 0.70

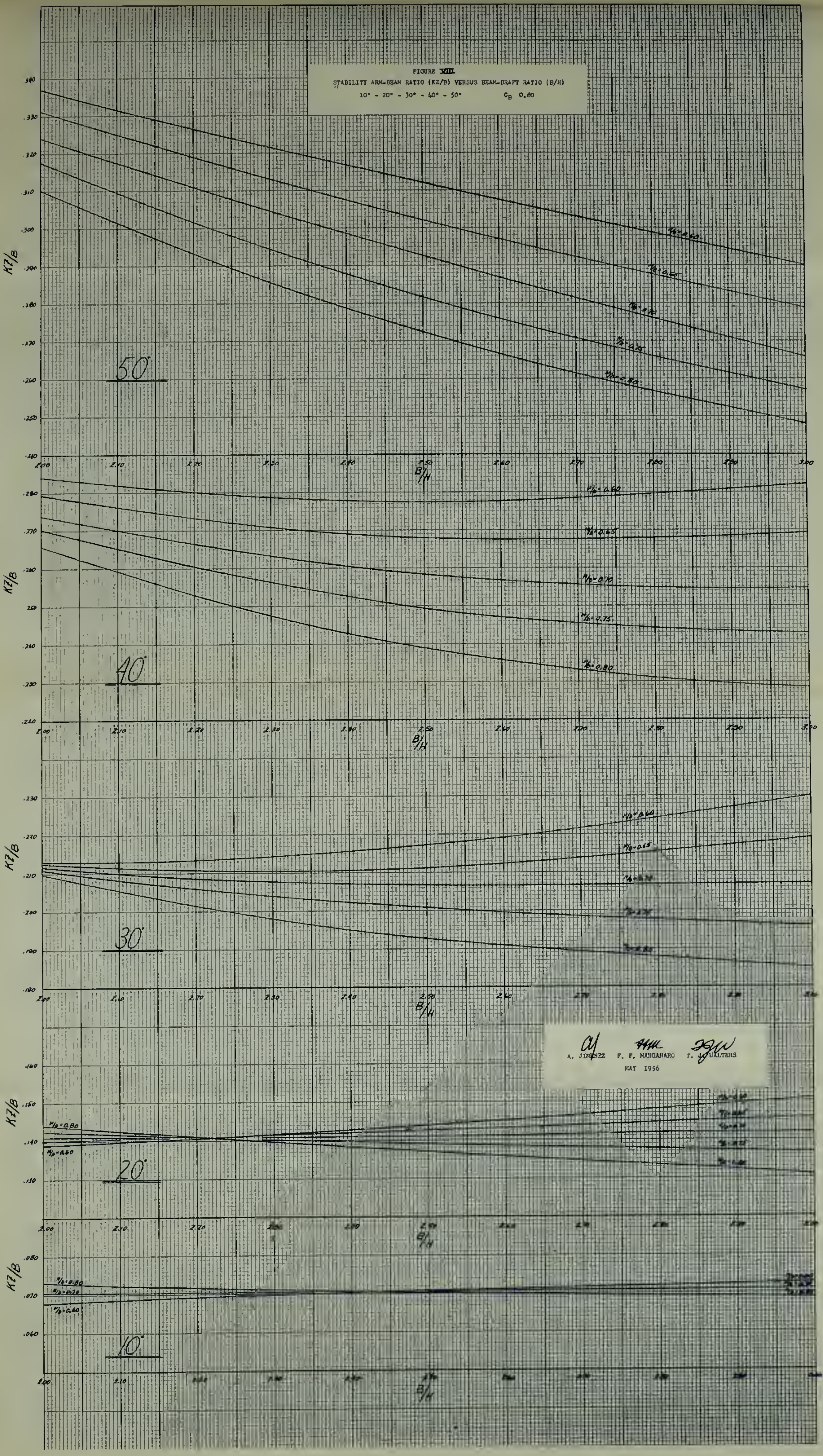
A. JIMENEZ F. F. MANGANARO T. J. WALTERS

MAY 1956

FIGURE VIII

STABILITY ARM-BEAM RATIO (KZ/B) VERSUS BEAM-DRAFT RATIO (B/H)

10° - 20° - 30° - 40° - 50° C_B 0.60



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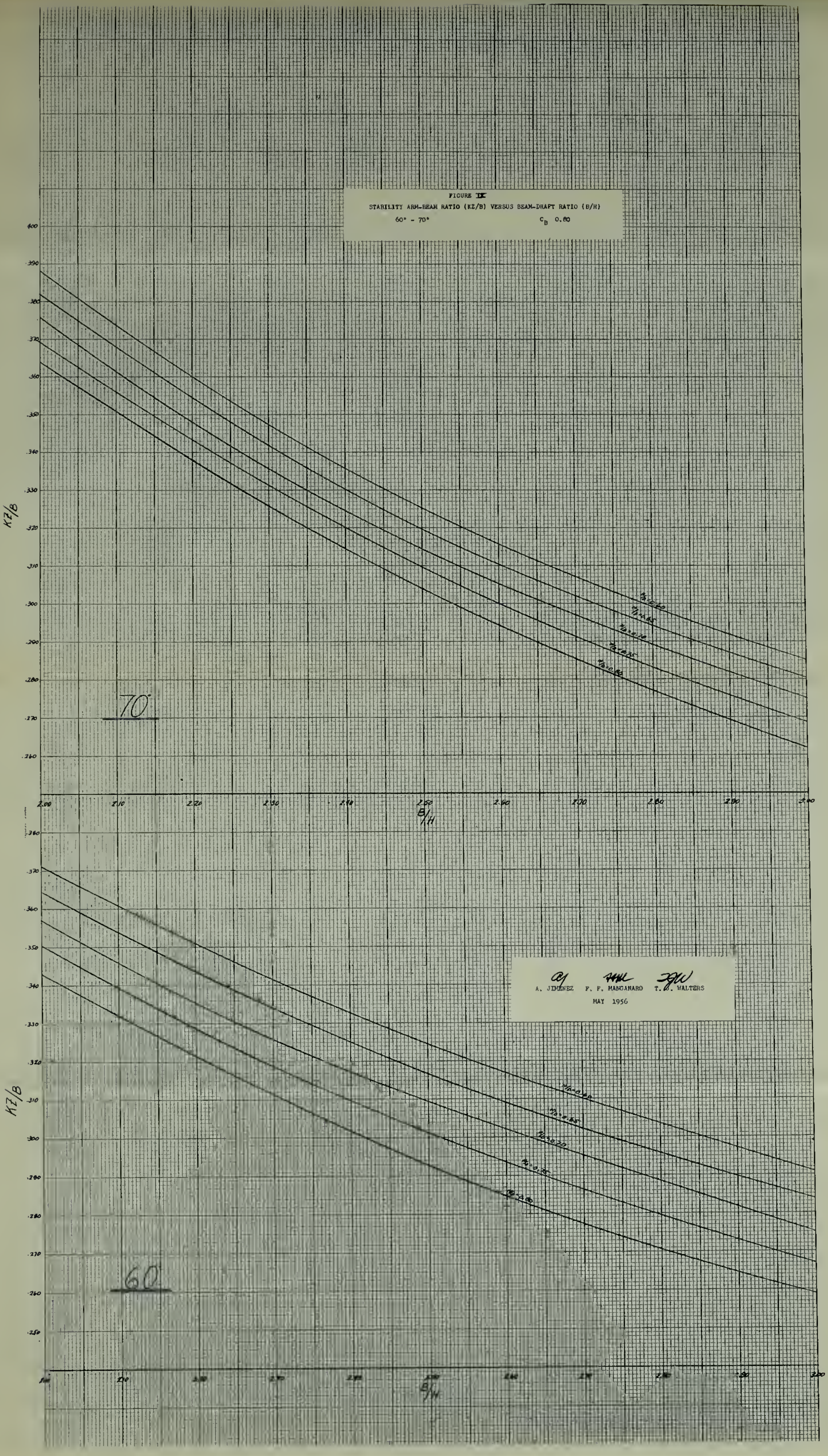

FIGURE IX

STABILITY ARM-BEAM RATIO (KZ/B) VERSUS BEAM-DRAFT RATIO (B/H)

60° - 70° C_B 0.60

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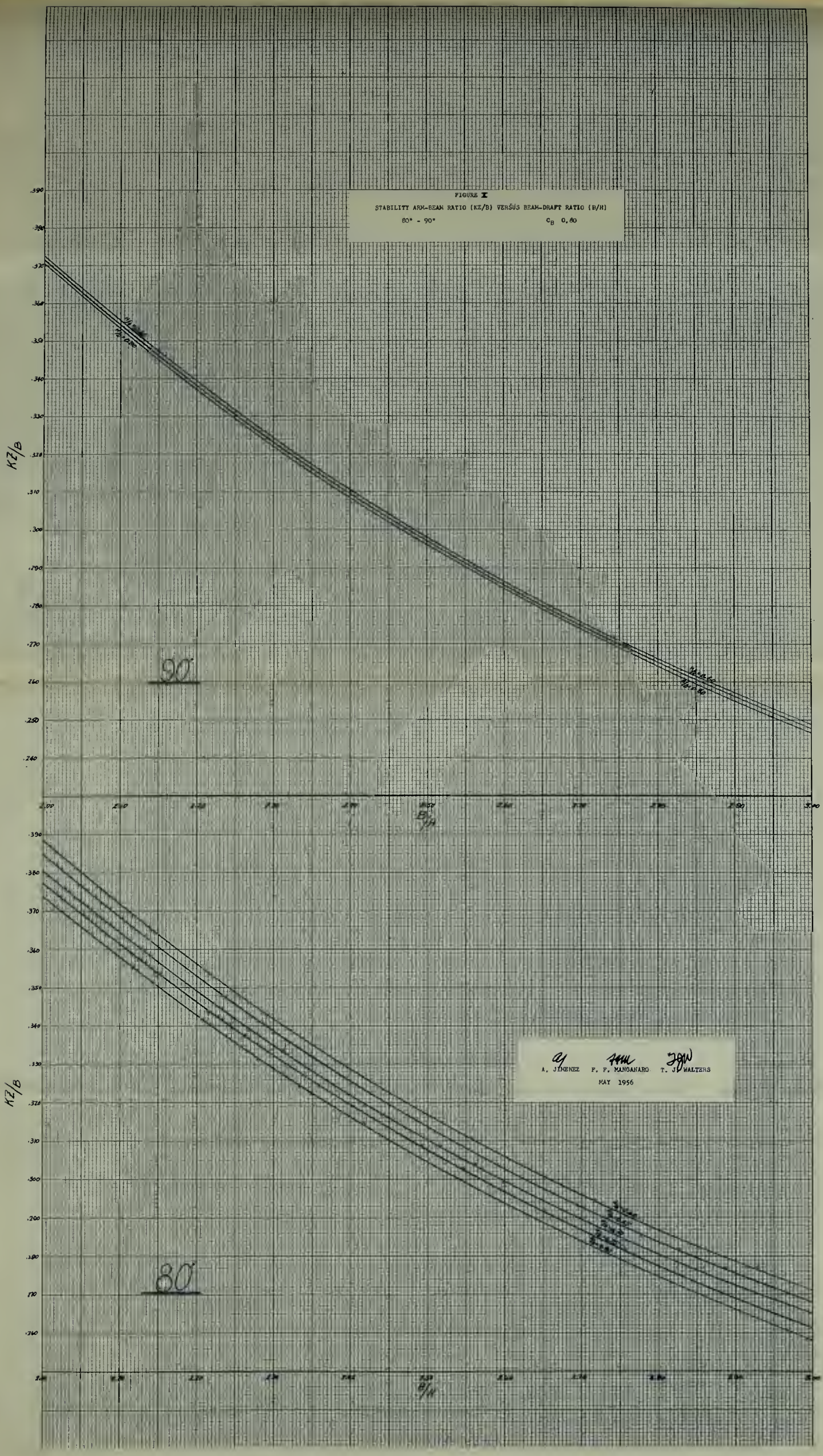

FIGURE I

STABILITY ARM-BEAM RATIO (KZ/B) VERSUS BEAM-DRAFT RATIO (B/H)

80° - 90° C_B 0.60

aj Ffm TJW

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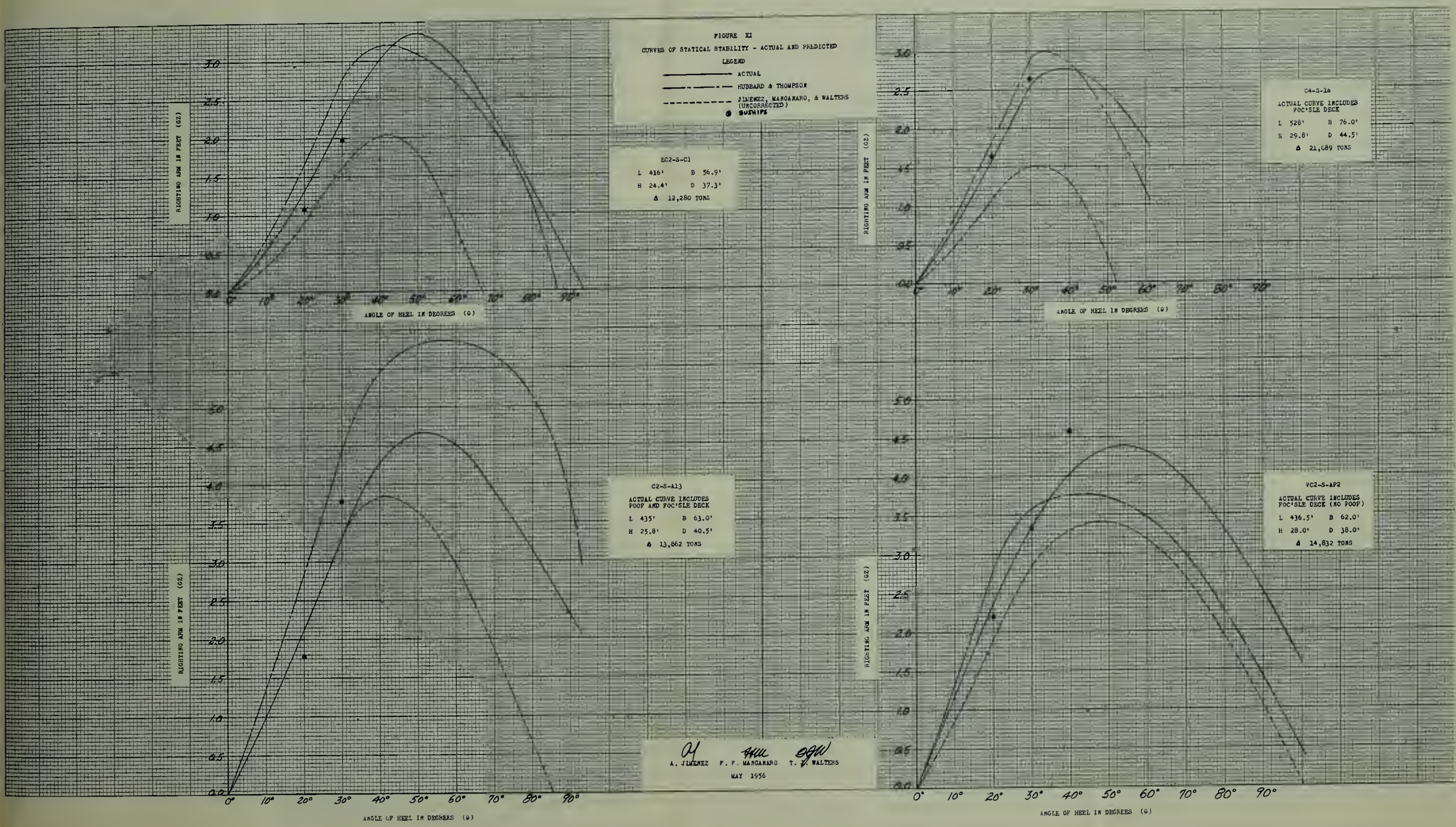
FIGURE XI

CURVES OF STATICAL STABILITY - ACTUAL AND PREDICTED



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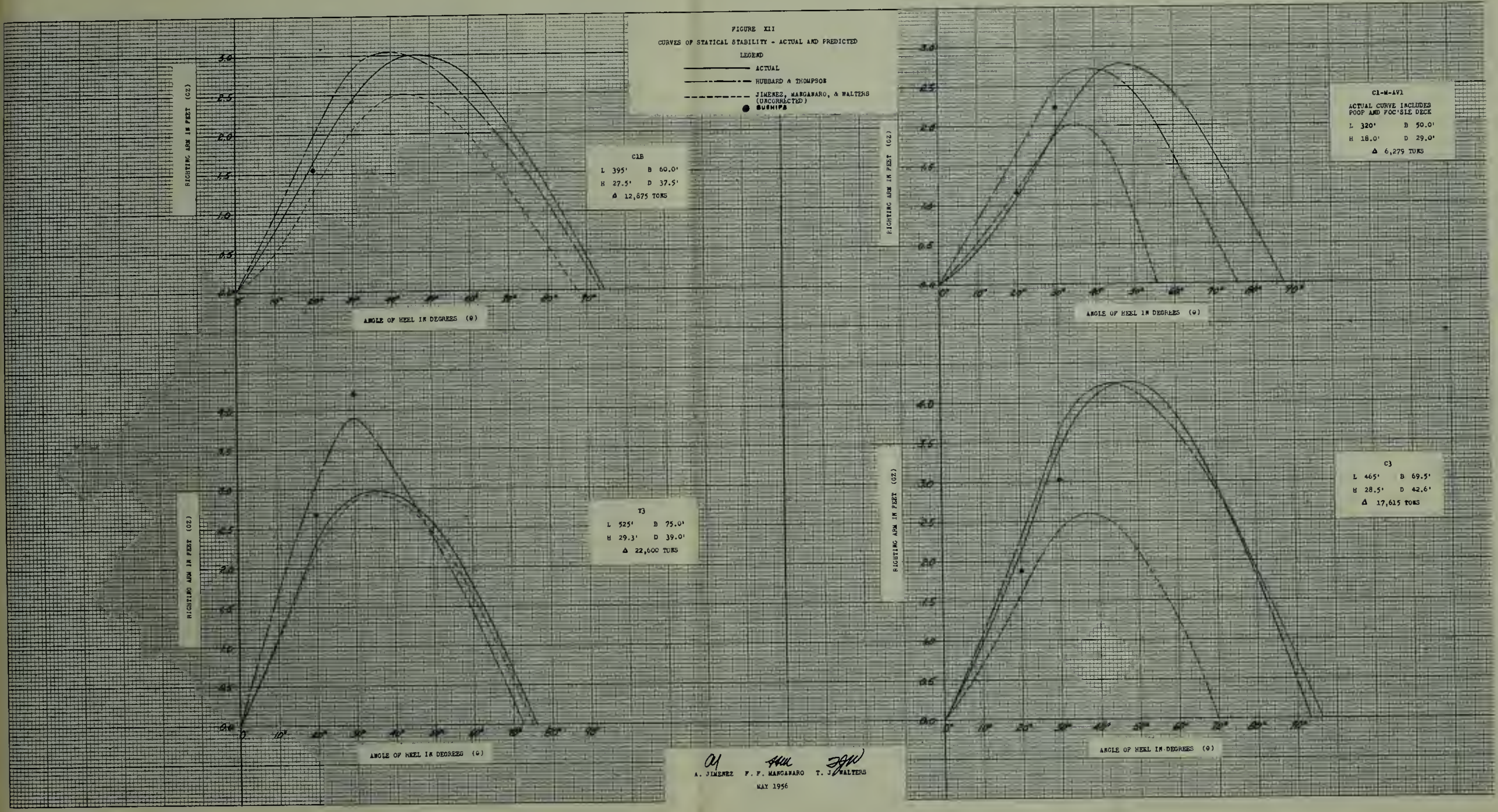

FIGURE XII

CURVES OF STATICAL STABILITY - ACTUAL AND PREDICTED

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MAY 1956

IV. DISCUSSION OF RESULTS

The comparative curves of stability shown in figures XI and XII illustrate several important points. Before discussing these, we should point out that no attempt has been made to correct our results for the effects of superstructure and the differences in shear and flare between the actual ships and our "parents." The only reason why this was not done was lack of time, and we fully realize that such a correction is necessary to obtain what may be called acceptable agreement. The curves predicted by the method of Hubbard and Thompson (Ref. 39) do include the shear correction devised by these authors.

Hubbard and Thompson's parameters were C_p, H/B, and B/D; their "parents" were Taylor series hulls with "flat tops" (i.e. no shear), and their data were generated by integrating a single parent and then expanding this data both longitudinally and transversely by the methods discussed in Appendices A and B. As discussed in these appendices, we have our reservations as to the degree of accuracy obtainable by these methods, and in the generation of our data we avoided the longitudinal expansion completely, and used a variation of the lateral expansion that we felt eliminated the inaccuracies that had arisen in previous investigations; however, as pointed out in Section VI, we have found that even with our more accurate method of predicting the location of the center of buoyancy of the parents, there are

intrinsic limitations in the accuracy obtainable in the graphical part of the expansion, and for this reason are recommending that the method be abandoned. The other differences of our method with that of Hubbard and Thompson are the use of series 60 parents with standard shear and normal flare, and the selection of C_p, B/H and H/D as parameters. Both methods tabulate the data in terms of KZ/B.

Comparing first the actual curves with those predicted by Hubbard and Thompson we may say that, in several cases, the agreement is quite acceptable for preliminary design purposes. Exceptions to this statement are the cases of the C2 and the T3, and to a smaller extent, that of the VC2. The initial slope is over-predicted in every case, and the angle at which maximum righting arm occurs is somewhat over-predicted. We were not able to arrive at a rational explanation of all these differences, and they may well be due simply to the fact that these are not Taylor series hulls. Many factors besides the ones considered have an influence on stability, the most obvious ones being shear, flare and C_x, and we feel that even after an approximate correction is introduced for shear, there is an intrinsic limitation to the accuracy obtainable by the parent form method due to the fact that form has such a powerful effect on stability, and that variations in form are possible (in fact, common) in ships of the same C_p and ratio of principal dimensions. This limitation, however, does not mean that useful data can not be generated for preliminary design, as the accuracy obtainable is well within the values required at that stage of the design.

The powerful influence of form is also pointed out in Ref. 42, an official United States Navy publication. This publication gives curves of KZ/B at angles of 20°, 30° and 40° for ships within a certain range of C_b, B/H and H/D. These curves were obtained by back-figuring from the actual cross-curves for 25 merchant ships and drawing a "mean" line through the points obtained. The curves were used to predict the stability of merchant ships taken over by the Navy during the last World War. This was a provisional measure and the actual curves were later obtained by integration. Comparison showed that although reasonably good agreement was obtained in many cases, there were several unexplainable cases of marked disagreement. This seems to confirm the conclusion at which we arrived in the previous paragraph. As a matter of interest, where possible these curves have been used to predict points for our eight ships, and these points are shown by "stars" in figures XI and XII. No attempt has been made to draw a curve through these points.

Proceeding now to compare our predicted curves with the actual curves, we observe that in general the shape of the predicted curves is the same as that of the actual curves but are lower at all angles, the difference being more marked at the high angles of heel. Exceptions to these statements are the case of the T3 tanker, where agreement is remarkably good all along, and those of the C2 and to a lesser extent the C1-M-AV1, where the initial part of the curve is predicted well enough but the high angles are considerably under-predicted. The fact that the form of the curves is good, and that the differences are all of the

same nature, makes us believe that very good agreement may be obtained by introducing suitable corrections for shear and superstructure. Rather than try to arrive at finished results at all costs - a very natural desire - we have preferred to spend a great deal of time in the selection of the parents, the generation of the data and the evaluation of the accuracy of the various steps in the process. We feel that "shortcuts" such as the methods of expansion or the use of over-simplified hull forms, and the desire of each group of investigators to arrive at finished results in a 20-hour thesis, have resulted in less coordination between the various efforts than might have been obtained by evolving an over-all plan and letting each group investigate thoroughly a particular phase. We believe that the extensive literature to be reviewed and the time-consuming nature of the work demand a somewhat different approach to the problem, and have oriented our recommendations (see Section VI) in this direction.

Although we have therefore not attempted to develop a method of correction, the following qualitative discussion may be of use to any future investigators who may try to develop a correction. The fact that the T3 tanker is predicted so well may arise from the fact that the shear that we chose for our parents corresponds (stability-wise) to typical modern tanker shear, despite the fact that we selected the standard shear prescribed by the Load Line Regulations for cargo ships. Further confirmation of this fact is that all other ships, except

the C2 and the C1-M-AV1, are low, as would be expected for ships which have considerably more shear than the T3 tanker. In the cases of the C1-M-AV1, C2, C4-S-1a and VC2, the low values predicted at high angles of heel can be explained by the fact that the cross-curves for these ships were generated including various elements of the superstructure, an effect which was completely absent in the parents from which we generated our data. The large effect of the superstructure is illustrated in page 113 of Ref. 7. With regard to the initial slope, the fact that in most cases the actual curves lie somewhere in between our prediction and that of Hubbard and Thompson might be due to the fact that the lines of the ships analyzed lie somewhere between Taylor series and series 60 lines.

In conclusion, we would like to point out that the magnitude of these corrections need not be at all large, as might appear from looking at the curves. The reason for this is the great sensitivity of GZ to variations of the parameter KZ/B. The most striking way to illustrate this is by means of an example. Take the most marked divergence between our predicted values and the actual curves, a difference of 3.27' in the value of GZ at 90° for the C3. To obtain perfect agreement, the value of KZ/B should vary the same as that of GZ/B, that is, $3.27/69.5 = .0470$, a small variation compared to values of KZ/B of about .3000 at this angle. In most cases, the difference is much smaller (see Appendix E).

V. CONCLUSIONS

The following conclusions are derived from our discussion of the results:

1. - Methods for the prediction of statical stability based on parent forms developed to date are capable of predicting reasonably well the stability of many ships of form similar to that of the parent, but there are several ships for which good agreement is not obtained and no rational explanation is apparent.
2. - The parameters C_b, B/H and H/D are adequate to describe the fundamental behaviour of ships stability-wise, but the influence of shear, flare and superstructure is so marked that the fundamental data must be corrected for their effect in order to obtain acceptable agreement. This is strikingly illustrated by the good agreement obtained by Hubbard and Thompson for several ships after shear is corrected for. We feel that because of the parents selected and the procedure followed, the shape of our curves closely resembles the actual curves and will provide very good agreement after a correction for shear, flare and superstructure is introduced. Such correction was not developed for lack of time.
3. - The parameter KZ/B is very convenient in that it eliminates the need to specify the assumed location of G every time,

but has the disadvantage that very small variations in its value produce considerable variation in the predicted values of GZ.

4. - The parent form method has been carried to the limit of what can be accomplished on a 20-hour thesis by the use of integrator methods. The use of a digital computer in future investigations is recommended. A program for such work is available (Ref. 24).

5. - A thorough investigation of the precision of measurements and calculations involved in the prediction method, along the lines suggested by (Ref. 13), is needed.

VI. RECOMMENDATIONS

As a result of the work done on this project, several recommendations suggest themselves. Some stem from the results themselves and others are derived from the problems encountered during the generation of the basic data.

Throughout the entire investigation, time was a major factor. Almost invariably, any step designed to increase the accuracy of the generated data or any check on the validity of a proposed method of obtaining data, without the tedious process of integrating, proved to be time consuming. This points out not only the desirability, but the necessity of providing complete data on all work done in an exploratory way when deciding on the particular procedure to be followed in the generation of data concerning the basic parameters. A group cannot hope to make real progress in the overall problem if it cannot make profitable use of the labors of previous investigators. This can only be done if, not only the method, but all the details of its derivation and its proof are provided.

Another factor in which time plays an important role is the question of assimilation of the existing information on the stability problem as it stands to date. The work of previous investigators has reached a volume such that a considerable amount of time is required to read and evaluate it sufficiently. As the problem is pushed further and further, the time required

to prepare for continued investigation becomes greater and greater. This would suggest that the problem be carried on by a full time investigator such as a graduate assistant.

Concerning specific aspects of the problem, there are several recommendations which must be made. Throughout the investigation, accuracy required continuous attention. A complete study of the precision of the data and methods of calculation involved in the generation of stability data, and of any other processes such as the lateral or longitudinal methods of expansion, should be done. Reference (3) is a short but good treatment of this subject , and reference (13) applies these ideas specifically to naval architectural calculations. It is felt that such a study would constitute a thesis in itself, and would be most helpful to any future investigators of the stability problem. Due to time limitations, we used the methods of reference (13) only as a guide with the exception of the integrator constants which were accurately determined.

From our consideration of the above references, we feel that the effort required to obtain the desired accuracy becomes unprofitable. In still others, the degree of accuracy is unknown. This latter conclusion is particularly true with respect to the expansion methods developed to facilitate the generation of data without requiring the laborious process of integration of many body plans. Therefore, it is recommended that the method of generating data by means of the longitudinal and lateral expansions be discontinued. This means that the basic data required, i. e. volumes and moments of many hulls, must be obtained by a single process whose accuracy can be ascertained.

The present investigators are of the opinion that the method of generation of the basic data by mechanical integrators has been carried out as precisely as is reasonable. Any further attempt to increase the accuracy of the process calls for an uneconomical expenditure of time. This, coupled with the obvious desirability of obtaining data for a large number of hulls at many water lines and at many angles of inclination requires that a new method of data generation be found. It is recommended that the method, as developed in this thesis, be adapted for calculation in the digital computer. The problem of intact stability has already been programmed for the computer (Ref. 24). It is entirely conceivable that a similar program could be developed to account for the desired variation in the basic parameters and to generate data for the various inclinations. Then, many, many hulls can be investigated to produce a large number of points in the cross curves of stability thus greatly reducing the amount of fairing in the basic data. This process also has the added advantage of generating all the information by means of a single process, the accuracy of which can be ascertained. The programming of the procedure and the generation of the basic data by this method could well be a thesis in itself. Furthermore, such a thorough investigation (as could be accomplished using the digital computer) coupled with a precise knowledge of the accuracy of the process, would once and for all show just how much accuracy the parent form method is capable of -- a point which we feel has not been definitely elucidated by the investigations to date.

It is also recommended that further investigation be carried on to ascertain the contribution to stability made by shear and watertight superstructure. As brought out in the discussion of results, watertight poop and foc'sle decks and the presence of shear other than standard shear play an important role in a vessel's stability after deck edge immersion. It will be necessary not only to investigate the magnitude of these effects, but also to separate them so that different combinations of the two can be considered.

VII. APPENDICES

APPENDIX A. SUPPLEMENTARY INTRODUCTION

Discussion of the Method of Longitudinal Expansion.

As mentioned in Part I, INTRODUCTION, our investigation started where Hubbard and Thompson (Ref. 39) had stopped. These investigators had used, in the generation of their data, the method of lateral and longitudinal expansion first used by Church and Robinson (Ref. 28). The method of lateral expansion is discussed in Appendix B since, with one modification, it has been used in our work. The method of longitudinal expansion was abandoned for two reasons: (1) the inability to apply it to series 60, where C_b is not varied by any geometrical process as in Taylor's series, and (2) some inaccuracies inherent in the system, which could only be eradicated by making the process just as laborious as integrating each hull independently. The purpose of this discussion is to elaborate on this last point.

Figure XIII illustrates the procedure used by Hubbard and Thompson. The lower portion of the figure represents the curves of sectional areas of the parent and of the hull to which it is desired to expand the data. The ordinates of these curves are given in (Ref. 41), and they refer to the load waterline of each ship. As is well known, Taylor uses the same stations for all the ships, and varies the C_p by relocating the stations longitudinally. For example, station 2 in the parent is identical

to station 2' in the offspring. Hubbard and Thompson drew above these curves one curve of areas and another one of moments of areas for each waterline and each angle of heel; these curves were obtained by taking the values obtained in their integration of the parent and plotting them at the proper "prime" position (1', 2'...). The resulting moment and area curves were then "Simpsonized" and their ratio, when multiplied by the proper constant, gave the value of KZ.

Our objection to the method arises from the use of the same curves of sectional areas for all waterlines. Both the parent curve and the offspring curve should really vary for each waterline, for the values of C_p of normal ship forms vary with draft. Although this variation of C_p is not very large, it produces considerable difference in the results, especially toward the ends where the area and moment curves rise or fall quite sharply. Differences as high as 10% were found in area and moment readings by introducing normal variations of C_p with draft. This convinced us that the inaccuracies introduced were unacceptable. The only way to avoid them is to plot a different curve of sectional areas for the parent and each offspring at each waterline, and to use the appropriate curve for each waterline for which data is to be generated. This would entail as much work as integrating the offspring, and is probably not as accurate.

2' Station used for all waterlines by ref.(39); correct for 4" W.L., Taylor Standard Series to go from C_p.552 to .640.

2" Correct station for 3"W.L. for ship with D.W.L.=4"W.L., design C_p.552. expanded to C_p .640 at 3" W.L.

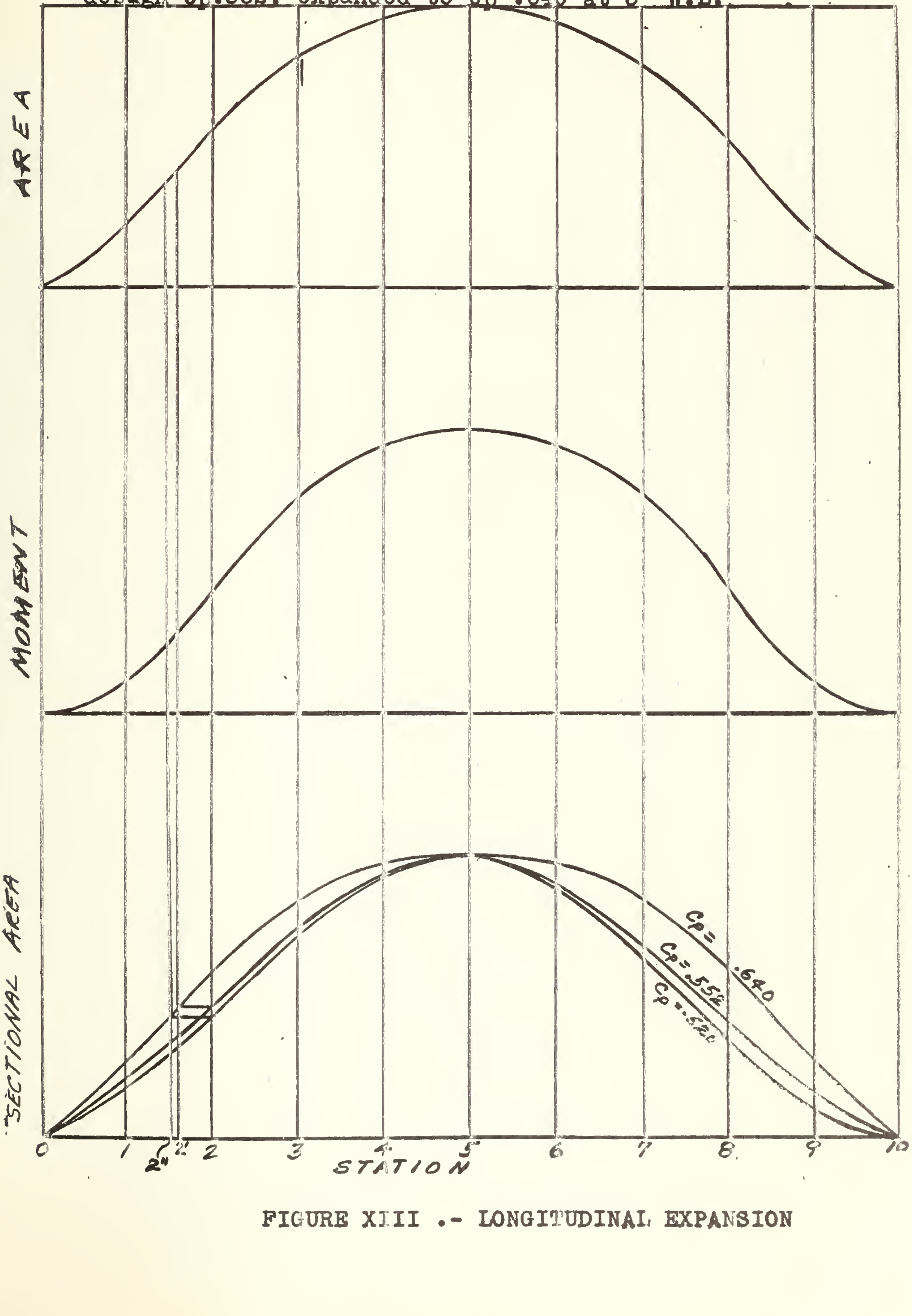

FIGURE XIII .- LONGITUDINAL EXPANSION

APPENDIX B. DETAILS OF PROCEDURE

Drawing of the Body Plans

The body plan for the series 60 parent with C_b of 0.70 was furnished to us by Professor Manning. This body plan had a beam of 10", a 1.00 WL draft of 4.27" (i.e. a B/H of 2.32), and a depth of 6.40", the main deck being simply a straight line (i.e. a ship with zero shear). For purposes of uniformity, and to avoid having to draw the body plan for the 0.70 parent again, the above beam and draft were adopted. The upper portion of the body plan, however, was redrawn to result in more realistic ship forms. Since an H/D of 0.75 had been found typical of tankers and full scantling cargo ships, a depth of 5.69" amidships was adopted for all parents. On this depth, standard shear as prescribed by the Load Line Regulations was superimposed. "Medium flare," as defined by Panel H-7 of the Society of Naval Architects and Marine Engineers for their seakeeping experiments on series 60, was used, the data being taken from body plans furnished by Professor M. A. Abkowitz. The important offsets are tabulated below for easy reference. The distance between stations was chosen as 7.5", thus giving a ship's length of 75" and an L/B of 7.5, exactly the midpoint of the range of L/B to be covered in the resistance investigation of series 60 (6.5 to 8.5). Besides, this spacing had the virtue of simplifying the arithmetic of the "Simpsonizing" process.

The table below gives the shear (which is the same for all three parents, since their length is the same) and the half-breadth at the 1.25 WL and at the deck at side. The offsets at the 1.00 WL and below are the standard series 60 offsets as given in Ref. 21. As previously mentioned, all the parents have a length of 75", a beam of 10", a depth of 5.69" and a draft of 4.27".

TABLE III. SHEAR AND HALF-BREADTHS OF PARENTS

Station	Shear	Parent #11		Parent #31		Parent #51	
		1.25 WL	Dk.at side	1.25 WL	Dk.at side	1.25 WL	Dk.at side
0	1.25"	.04"	.35"	.10"	.50	.17"	.64"
½	.992	.64	1.05	1.14	1.64	2.76	3.20
1	.785	1.32	1.84	2.34	2.73	4.24	4.38
2	.462	3.01	3.30	4.26	4.36	5.00	5.00
3	.228	4.32	4.42	4.93	4.94	5.00	5.00
4	.072	4.90	4.91	5.00	5.00	5.00	5.00
5	.000	5.00	5.00	5.00	5.00	5.00	5.00
6	.022	5.00	5.00	5.00	5.00	5.00	5.00
7	.097	4.95	4.97	4.99	5.00	5.00	5.00
8	.222	4.68	4.82	4.70	4.82	4.86	4.92
9	.400	3.56	4.06	3.80	4.20	4.47	4.47
9½	.505	3.02	3.40	2.82	3.48	3.35	3.80
10	.625	1.37	2.13	1.40	2.24	1.85	2.32

Integration Procedure

In Part II, PROCEDURE, we have already given the standardized procedure followed in the integration process, and here we will only mention a few additional details.

The integrators used were Integrators #1 and #2 of the Department of Naval Architecture Plans and Files Office, manufacturer's number 433 and 435 respectively. We shall call the "area constant" the number by which the difference in readings of the area dial must be divided to give area in square inches, and "moment constant" the number by which the difference in readings of the moment dial must be divided to obtain the moment in square inches x inches. These constants were originally calibrated at the factory to be 50 and 25 respectively, but we found that small differences in the value of the constants produced considerable differences in the results, and decided to take a statistical average. The integrators were checked on different days, going around areas of different sizes and orientations, and the following arithmetical means were arrived at:

	Area Constant	Moment Constant
Integrator #1	49.60	24.63
Integrator #2	49.55	24.89

These constants were used throughout, At each angle five waterlines were chosen, spaced as described in Part II. The first integration was up to the lowest WL. the next then went between the lowest WL and the next one, and so on. By this method of "slices" considerable integrating time was saved.

Each waterline was recorded in a standard form, a sample of which is shown in Appendix D. The five waterlines corresponding to a given hull and angle formed a "book" and were calculated cumulatively, adding up the slives. The functions of areas and the quotient of the functions of moments divided by the functions of area, when multiplied by the proper constants (depending on the integrator used) gave the values of displacement and KZ. All this can be seen more clearly in Appendix D. Of course when we were forced to shift the integrator axis 1" parallel to itself (i.e. KG sin θ equal 1"), 1" was added to the value of the quotient in order to obtain KZ.

Each reading was taken twice, and if the disagreement was more than 2% additional readings were taken until a consistency within 2% was obtained. When the difference in readings was below 100 we relaxed this rule somewhat, for we found that the 2% rule was practically impossible to apply for very low readings: the instrument just isn't that accurate.

The sign of the moments is important. By always going clockwise, we automatically knew that decreasing dial readings meant plus moments (i.e. away from the track). Besides this, however, it is important that the position of the track with respect to the body plan always be the same, otherwise although the sign convention with respect to the integrator has not changed, the one with respect to the baseline or the centerline of the ship does change, and if this change is made in the middle of the process it can lead to all sorts of trouble.

The Method of Lateral Expansion

In their thesis, Hubbard and Thompson mentioned that part of the lack of agreement in the use of their curves of KZ/B may have been due to inaccuracies in the method of lateral expansion, so it was decided to investigate this method thoroughly to determine if its use was advisable.

Analytical Proof.

The method of lateral expansion was first used, to our knowledge, by Church and Robinson (Ref. 39); they did not publish, however, an analytical proof of the method. Hubbard and Thompson also used the method, and gave a partial proof of it. We have therefore considered it worthwhile to include the following proof, which we consider complete and general enough to apply to any ship form, regardless of flare and shear, and at all angles of inclination.

Figure XIV shows two hulls: (a) a parent hull whose cross curves of stability are available, and (b) a "derived" hull obtained by multiplying all horizontal distances in the parent by a constant C (which may be greater or smaller than 1), and leaving all vertical distances unchanged. We desire to obtain the cross curves for the derived hull without having to go through the complete integration process again.

Suppose that we have a means of locating B_1 (this point will be elaborated later). Obviously if we can predict the location of B_2 we can easily measure K_2Z_2, the stability arm of the derived hull. Let us proceed as follows. W_1L_1 represents

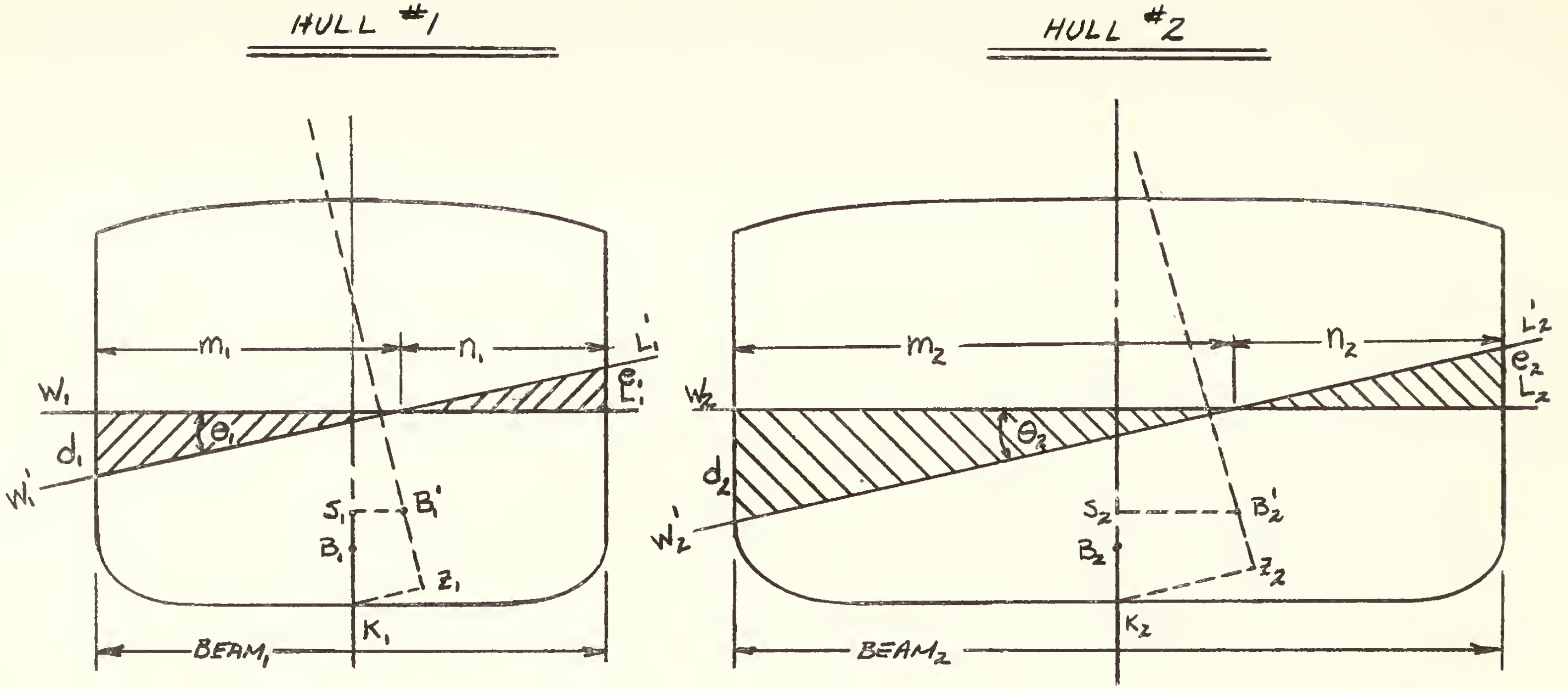
HULL #1
HULL #2
m_1
n_1
L_1'
e_1
L_1
W_1
θ_1
d_1
W_1'
S_1
B_1'
B_1
Z_1
K_1
$BEAM_1$
m_2
n_2
L_2'
e_2
L_2
W_2
θ_2
d_2
W_2'
S_2
B_2'
B_2
Z_2
K_2
$BEAM_2$

FIGURE XIV

LATERAL EXPANSION DERIVATION
NOT TO SCALE

the upright waterline of hull (a), and B_1 the corresponding center of buoyancy; W_2L_2 and B_2 represent the same for hull (b). Suppose now that hull (a) is inclined ~~θ_1~~ degrees, and as a result B_1 shifts to B'_1. S_1B_1 and $S_1B'_1$ represent the components of the shift of the center of buoyancy along the centerline and normal to it, respectively. We next measure d_1 and e_1, the distances intercepted between waterlines in the line parallel to the centerline and passing through the original intersection of the waterline and hull. Lay off now distances d_2 and e_2 in hull (b), equal to d_1 and e_1 respectively, and draw $W'_2L'_2$, which will represent an inclination of $\theta_2 = 1/C \tan \theta_1$. Now measure the distance $S_1B'_1$, multiply it by C and lay it down as $S_2B'_2$, where K_1S_1 and K_2S_2 are equal. We claim that this locates B'_2 correctly, and that by then passing through B'_2 a perpendicular to $W'_2L'_2$, and dropping a perpendicular from K_2 to this line, the desired K_2Z_2 is obtained (corresponding to angle θ_2, of course). The proof is as follows:

Let V_1 represent the volume of displacement of a slice of the ship, one unit long, measured into the paper. Equating the moment transfers about the base line, we then have:

$$(V_1)(S_1B_1) = \tfrac{1}{2}m_1d_1(d_1/3) + \tfrac{1}{2}n_1e_1(e_1/3)$$

$$(V_2)(S_2B_2) = \tfrac{1}{2}m_2d_2(d_2/3) + \tfrac{1}{2}n_2e_2(e_2/3)$$

But: $V_2 = CV_1 \qquad m_2 = Cm_1 \qquad n_2 = Cn_1$

$\qquad e_2 = e_1 \qquad d_2 = d_1$

$$\therefore (CV_1)(S_2B_2) = \tfrac{1}{2}Cm_1 \; d^2{}_2/3 + \tfrac{1}{2}Cn_1 \; e_2{}^2/3$$

$$\therefore \quad S_2B_2 = S_1B_1$$

And $\quad K_1B_1 = K_2B_2$, by inspection

$\therefore \quad \underline{KS_1 = KS_2} \quad$ Q.E.D.

Equating now the moment transfers about the centerline:

$$(V_1)(S_1B'_1) = \tfrac{1}{2}m_1d_1(2/3\ m_1) - \tfrac{1}{2}n_1d_1(2/3\ n_1)$$

$$(V_2)(S_2B'_2) = \tfrac{1}{2}m_2d_2(2/3\ m_2) - \tfrac{1}{2}n_2d_2(2/3n_2)$$

$$\therefore\ (CV_1)(S_2B'_2) = \tfrac{1}{2}Cm_1d_1\ C\ 2/3\ m_1 - \tfrac{1}{2}Cn_1d_1\ C\ 2/3\ n_1$$

$$\therefore\quad \underline{S_2B'_2 = C(S_1B'_1)} \qquad \text{Q.E.D.}$$

Observe that although triangular wedges have been used for simplicity of presentation, the proof would hold at angles greater than the angle of deck edge immersion. Instead of the ½ and 2/3 associated with triangles we would now have some other numbers, but because of the way in which we have drawn the derived hull, these new numbers would be laterally expanded by C and would remain unaltered vertically, and we would arrive at exactly the same result.

The Location of B_1.

The previous section has shown that if B_1 is known, K_2Z_2 can be predicted. This prediction is not for the same angle or displacement as the parent, but the relations between angles and displacements are known and the cross curves can therefore be drawn. We will now discuss how B_1 is located to start with.

The method followed by Hubbard and Thompson will first be described. It is based on the well known property of a curve of displacement vs. draft, that the area above this curve, divided by the displacement, gives the vertical distance between the center of buoyancy and the waterline corresponding to the draft in question. A proof of this theorem is given

in Reference 2. Although this proof is for a ship in the upright position, the theorem is true for any inclination provided that "draft inclined" be read, that is, draft measured parallel to the centerline of the ship. When Hubbard and Thompson did their integration for KZ, they were careful to note what "draft inclined" each of their waterlines corresponded to, and were thus able to plot a curve of draft inclined vs. displacement, from which the second coordinate of B_1 can be obtained. The first coordinate, of course, is obtained from the known value of K_1Z_1, since a vertical (i.e. normal to W_1L_1) line through Z_1 will contain B_1.

Test of Hubbard and Thompson's Method.

In order to check the accuracy of the above method, Hull #11 was integrated at 0, 10, 45 and 75 degrees, and cross curves of stability were drawn. Hull #11 is the block .60 parent, with a beam of 10" and a depth of 5.69". We next integrated Hull #12, which has the same block coefficient and depth, but has been laterally expanded to a beam of 12.8", at angles of $7^{\circ}51'$, 38° and $71^{\circ}04'$, these being the "corresponding" angles according to the method of lateral expansion. In this work, our accuracy was comparable to that of Hubbard and Thompson, and perhaps even a little better because we spread our waterlines to cover a wider range of displacement.

We then predicted the value of KZ at these three angles by the method of lateral expansion outlined above. In the measurement of draft inclined it is important to be consistent in the reference point used. We used the line through K

parallel to the waterline, and although this has the disadvantage of having "negative" drafts since part of the ship extends below this line, it is an easily defined line. The comparison of the values obtained by the two methods was disappointing, as shown by the following table:

Inclination of parent	10°	45°	75°
Predicted KZ for expanded hull	.7080	2.709	3.480
Actual (integrated) KZ	.6950	2.769	3.405

An investigation was then started to determine the source of the inaccuracy. It was found that the location of B_1, as located by Hubbard and Thompson's method, did not agree with that obtained by doing a second integration with the axis of the integrator in the line through K parallel to the inclined waterline, that is, at 90° to the position for the determination of KZ. Since we were reasonably sure of the accuracy of our integration and the method of using the displacement curve is mathematically exact, the only possibility was that the displacement curve itself was not accurate enough. Hubbard and Thompson had expressed that their doubts were due to the relatively few number of points at low drafts, and we thought we had obviated this difficulty by our spreading of the waterlines, having gone down to waterlines as low as 1" for 45° inclination, and -2" for 75° (Hubbard and Thompson's lowest was the 3" waterline). Since even these low waterlines left a considerable portion of the curve to be faired, and a look at the physical picture (with stations not only decreasing in area at a very rapid rate, but actually emerging from the water) hinted at a

curve of extremely sharp curvature toward the end, it was decided to actually get points for the curve at waterlines spaced 1" apart all the way down to zero displacement. The results surpassed our expectations. The curve of displacement vs. inclined draft changed so radically in the low draft region that changes of as much as 10% in the area over this curve were obtained, with corresponding changes in the distance from the waterline to the center of buoyancy. By introducing this correction, agreement in the location of B_1 as determined by the two methods was obtained, and furthermore, with the corrected location of B_1 the method of lateral expansion gave excellent agreement in the predicted as compared to the integrated values of KZ.

It was therefore concluded that the method of lateral expansion was capable of giving predicted values of KZ for the expanded hull within the desired accuracy so long as adequate steps were taken to maintain accuracy in the determination of B_1. We believe that inaccuracies of at least 10% were introduced for this reason in the lateral expansions of Church and Robinson as well as Hubbard and Thompson, which would account in part for the lack of agreement they found when they tried to predict the stability of actual ships.

We decided that the method of integrating twice in two perpendicular directions, although perhaps a little more laborious, had the added advantage of better accuracy and ease of checking (since there would be two independent

determinations of areas and volumes). Actually the method based on the displacement vs. draft curve became almost as long when enough points were plotted at the lower drafts. For all these reasons, the "double" integration method was therefore adopted in this thesis.

APPENDIX C. SUMMARY OF DATA AND CALCULATIONS

This appendix includes:

1. Table IV. Dimensions of Merchant Ships.
2. Cross Curves of Stability received from the U. S. Maritime Commission. Figs. XV through XXII.
3. Table V. Data for ships used in the comparison of Results.
4. Summary of KZ and KZ/B from Series 60 as generated in this thesis, Table VI.
5. Prediction of the Statical Stability by the Method of Hubbard and Thompson for the ships of item 3 above; Table VII.
6. Prediction of statical stability from our curves (uncorrected) for the ships of item 3; Table VIII.
7. Calculation of points by the method of Ref. 42.

Items 1 and 2, although they do not constitute data generated by the authors, have been included because they may be of use to future investigators.

TABLE IV. DIMENSIONS OF MERCHANT SHIPS

A. Tankers

Source	L BP	B	D	H	H/D	B/H	Other Data
USMC Projected T5-S-RM2a "Pipeline"	595	80	44.5	34.75	.781	2.30	31345 tons FL
Ref.1 Tanker "E"	535	75	40.5	31.7	.784	2.36	C_b.698 C_p.702
Ref.2 Tanker "F"	600	82.5	42.5	31.9	.749	2.59	C_b.764 C_p.770
Ref.2 Tanker "G"	677	93	48.5	36.6	.754	2.54	C_b.755 C_p.765
Ref.10 Tanker	480	65.2	35.8	28	.772	2.33	
SSR*Year 1955 Dutch Tanker	630	86	45	34.2	.760	2.52	31165t. 16½ kts.
SSR 9-15-55 Danish tanker	545	70.5	38.75	29.25	.755	2.40	18250t. 15 kts.
SSR 9-15-55 "Venator" Swed.	525	71.75	38.5	29.5	.766	2.43	
SSR Year 1954 "Tina Onassis"	721.8	95	51.5	37.5	.729	2.53	45750t.
BMS** Aug. '55 German tanker	540	72	37.8	30.3	.802	2.38	14 kts.

B. Full Scantling Cargo Ships

USMC C4-S-A4	496	71.5	44.5	32.8	.738	2.18	C_b.654 C_p.665
USMC EC-2 "Liberty"	416	56.9	37.3	27.6	.739	2.05	C_p.760 C_x.987
USMC VC2-S-AP3 "Victory"	436.5	62.0	38.0	28.5	.749	2.21	C_b.682 C_p.691
USMC C1-B	395	60	37.5	27.6	.737	2.17	12875 t.
Ref.10, 3 island cargo ship	420	57	34.5	25.5	.740	2.24	
SSR*-6-23-55 "Balkis" Norw.	340	50	28.8	22.3	.774	2.24	16.4 kt.
SSR 9-15-55 Cargo-Pssgr.	456	62.4	38.2	27.3	.714	2.28	

TABLE IV. (continued)

C. Shelterdeckers

Source	L_{BP}	B	D	H	H/D	B/H	Other data
USMC "Freedom" Proj.C2-S-RM15a	417	65	39	26.5	.680	2.45	13350t.
USMC "Island" Proj.C1-M-RM17a	350	57	32	21	.656	2.71	7960t.
USMC "Clipper" Proj. C3-S-RM18a	460	73	41.3	28	.678	2.61	16900t.
USMC "Seafarer" Proj.C4-S-RM19a	494	74.5	44.5	29.75	.669	2.50	20330t.
USMC C4-S-1a "Mariner"	528	76	44.5	29.8	.669	2.55	C_b.612 C_p.625
USMC C2-S-B1 Ref.1 "A"Ship	435	63	40	25.75	.644	2.45	C_b.683 C_p.697
USMC C3	465	69.5	42.5	28.6	.672	2.43	C_b.658 C_p.670
Ref.10 ship	335	47.8	32.67	22.1	.676	2.16	12.5 kt.
Ref.10 ship	465	62	42.9	27.6	.644	2.24	16.25 kt.
SSR* Year 1954	395	55	33.5	22.25	.664	2.47	Canadian
BMS** Aug. 55	445	62	40.1	26.9	.670	2.30	British
BMS Nov. 54	421.6	60	36.4	25	.687	2.40	French
BMS Nov. 54	452.3	58.6	38	26.1	.687	2.24	British
BMS Nov. 54	262.4	42.9	27.6	17.9	.648	2.40	Danish
BMS June '55	498	70	42	28.8	.685	2.43	British
BMS June '55	450	61	38.7	26.6	.687	2.29	C_b.704
BMS Dec. 55 M/S "Orilla"	445	62	40.15	26.95	.670	2.30	

* SSR Shipbuilding and Shipping Record

** BMS British Motor Ship

USMC United States Maritime Commission. "Proj." means that ships are projects, have not been built yet.

All depths of shelterdeckers refer to the shelter deck.

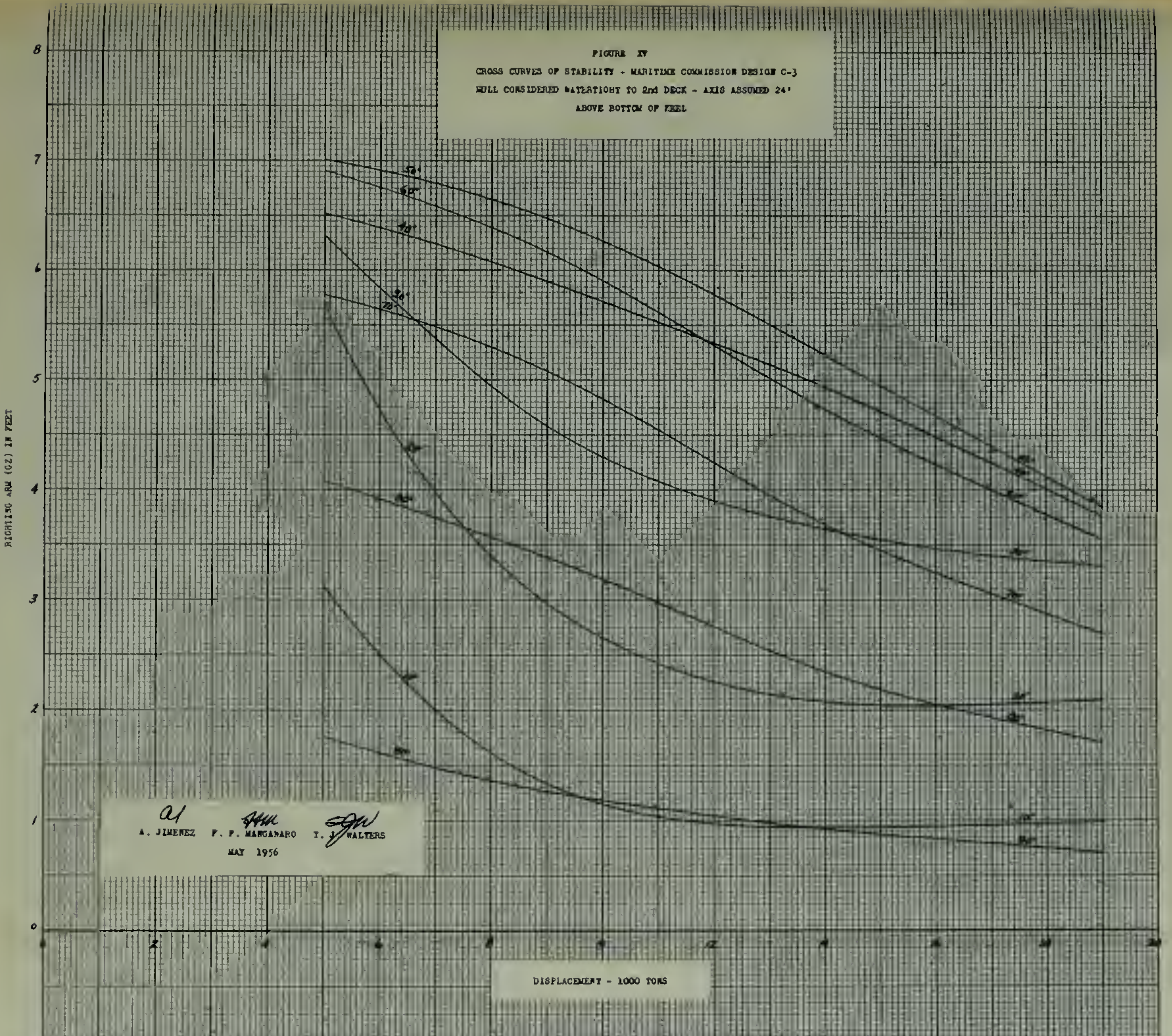

FIGURE XV

CROSS CURVES OF STABILITY - MARITIME COMMISSION DESIGN C-3
HULL CONSIDERED WATERTIGHT TO 2nd DECK - AXIS ASSUMED 24'
ABOVE BOTTOM OF KEEL

A. JIMENEZ F. F. MANGANARO T. J. WALTERS
MAY 1956

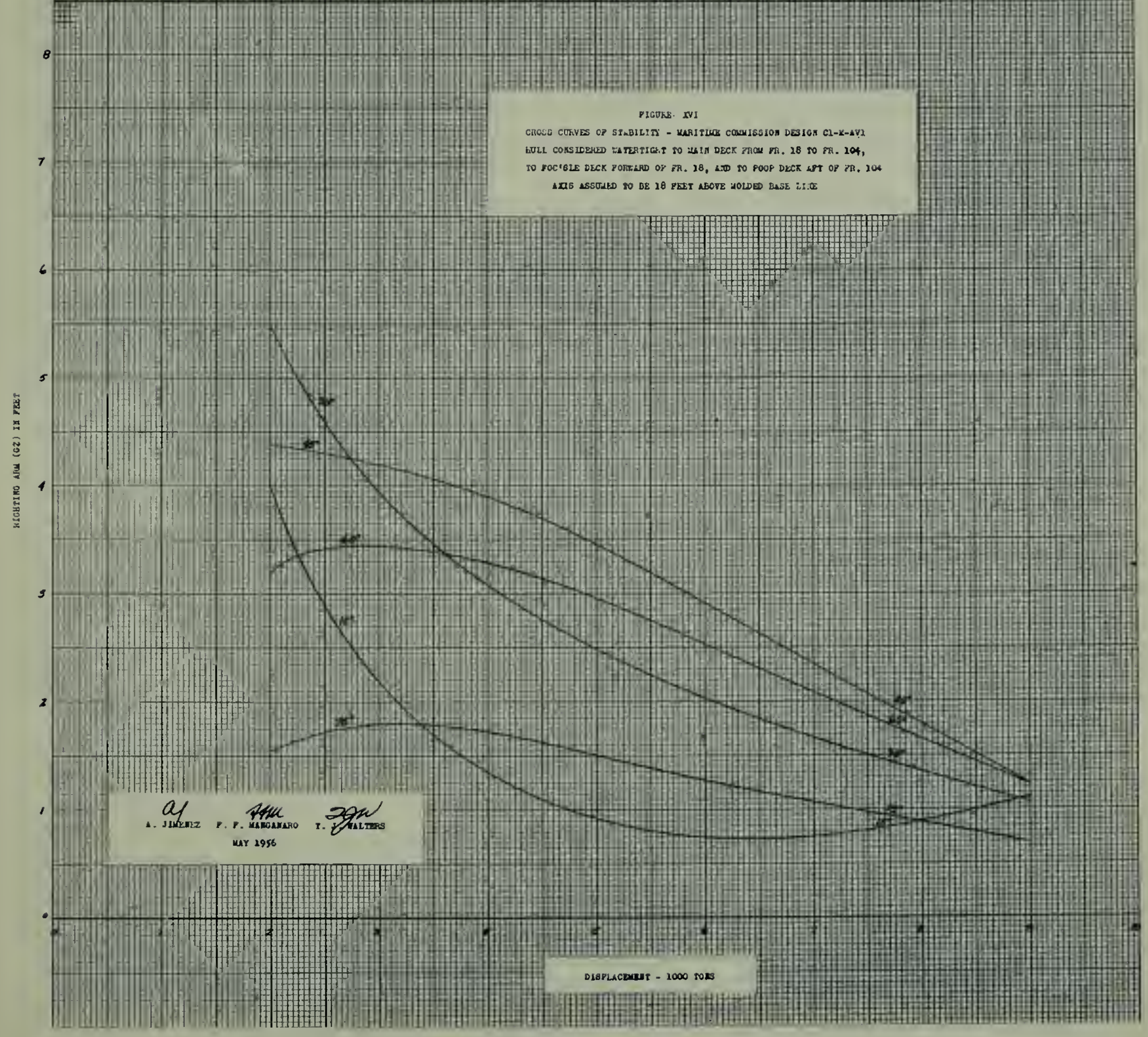

FIGURE XVI

CROSS CURVES OF STABILITY - MARITIME COMMISSION DESIGN C1-M-AV1
HULL CONSIDERED WATERTIGHT TO MAIN DECK FROM FR. 18 TO FR. 104,
TO FOC'SLE DECK FORWARD OF FR. 18, AND TO POOP DECK AFT OF FR. 104
AXIS ASSUMED TO BE 18 FEET ABOVE MOLDED BASE LINE

A. JIMENEZ F. F. MANGANARO T. J. WALTERS
MAY 1956

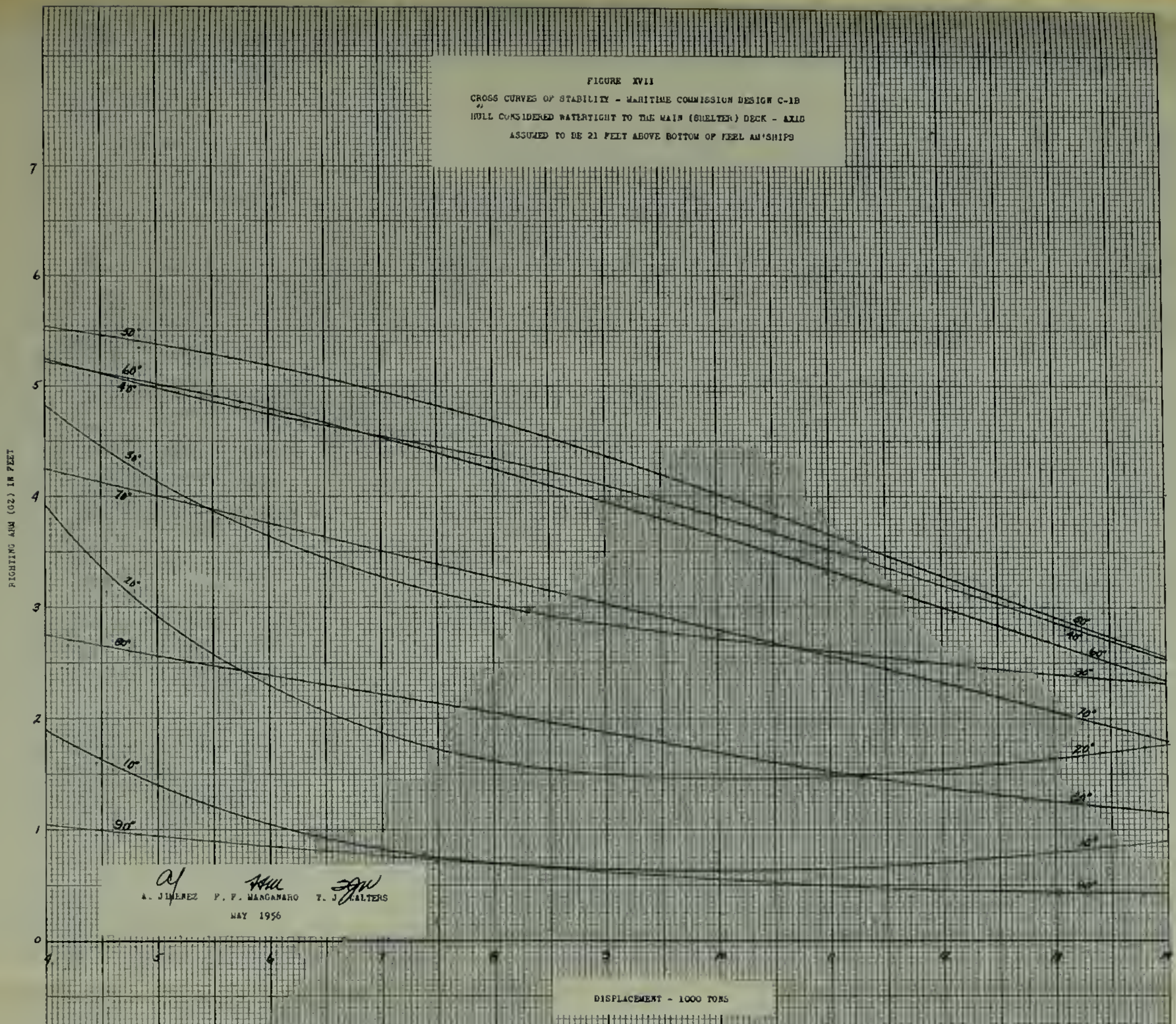

FIGURE XVII

CROSS CURVES OF STABILITY - MARITIME COMMISSION DESIGN C-1B
HULL CONSIDERED WATERTIGHT TO THE MAIN (SHELTER) DECK - AXIS
ASSUMED TO BE 21 FEET ABOVE BOTTOM OF KEEL AM'SHIPS

A. JIMENEZ F. F. MANGANARO T. J. WALTERS
MAY 1956

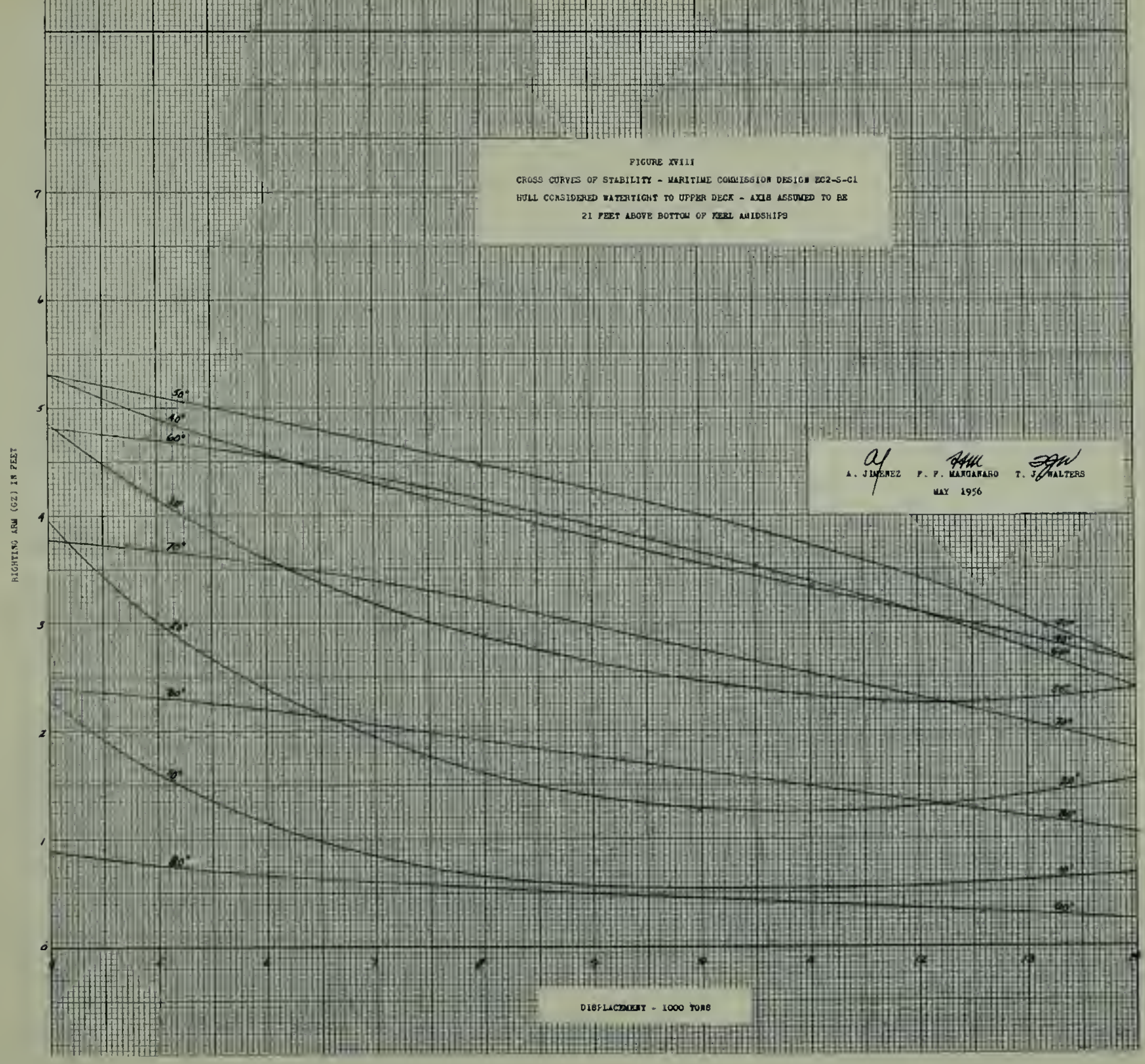

FIGURE XVIII

CROSS CURVES OF STABILITY - MARITIME COMMISSION DESIGN EC2-S-C1
HULL CONSIDERED WATERTIGHT TO UPPER DECK - AXIS ASSUMED TO BE
21 FEET ABOVE BOTTOM OF KEEL AMIDSHIPS

A. JIMENEZ F. F. MANGANARO T. J. WALTERS
MAY 1956

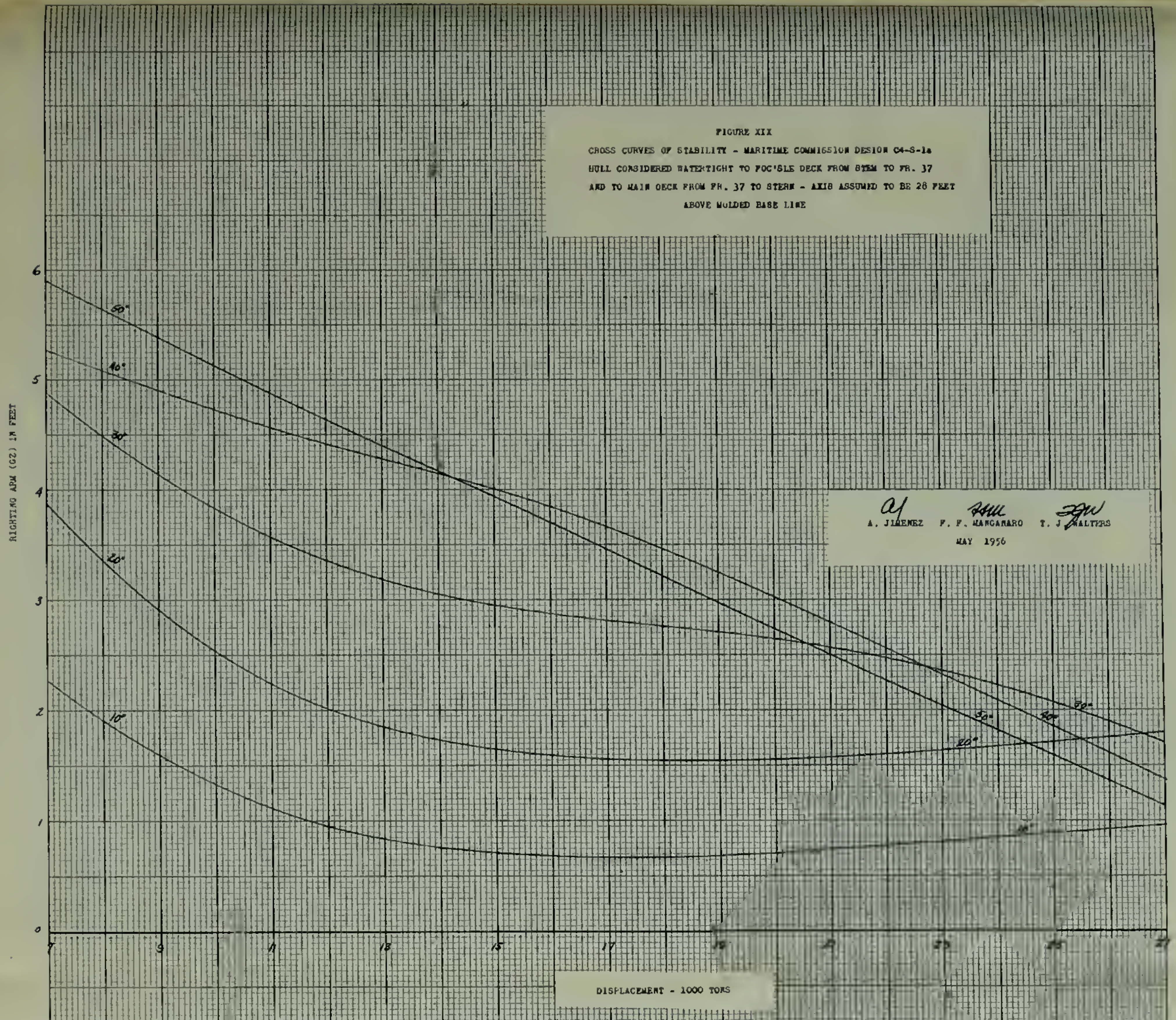

FIGURE XIX

CROSS CURVES OF STABILITY - MARITIME COMMISSION DESIGN C4-S-1a
HULL CONSIDERED WATERTIGHT TO FOC'SLE DECK FROM STEM TO FR. 37
AND TO MAIN DECK FROM FR. 37 TO STERN - AXIS ASSUMED TO BE 28 FEET
ABOVE MOLDED BASE LINE

A. JIMENEZ F. F. MANCANARO T. J. WALTERS
MAY 1956

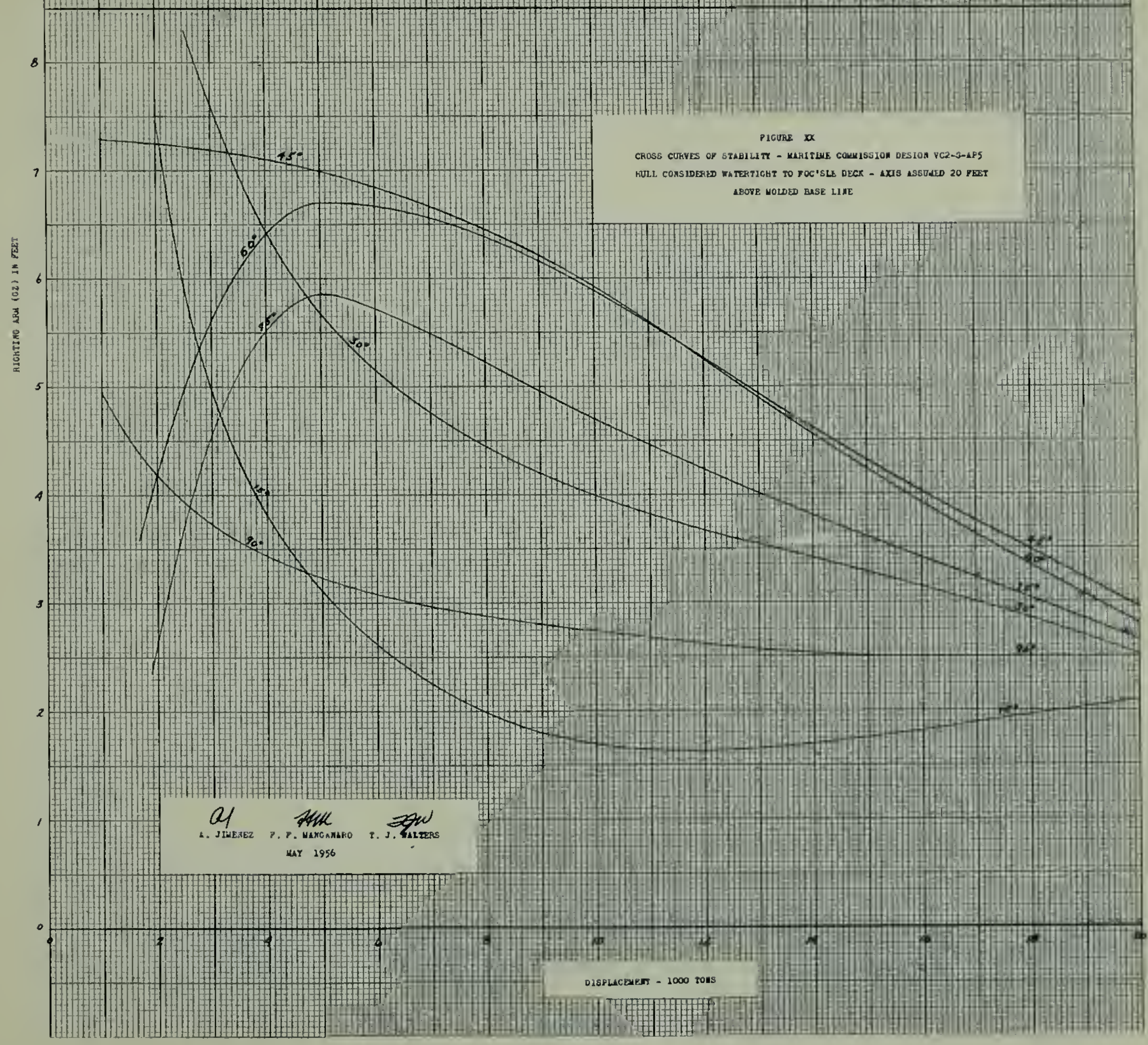

FIGURE XX

CROSS CURVES OF STABILITY - MARITIME COMMISSION DESIGN VC2-S-AP5
HULL CONSIDERED WATERTIGHT TO FOC'SLE DECK - AXIS ASSUMED 20 FEET
ABOVE MOLDED BASE LINE

A. JIMENEZ F. F. MANCANARO T. J. WALTERS
MAY 1956

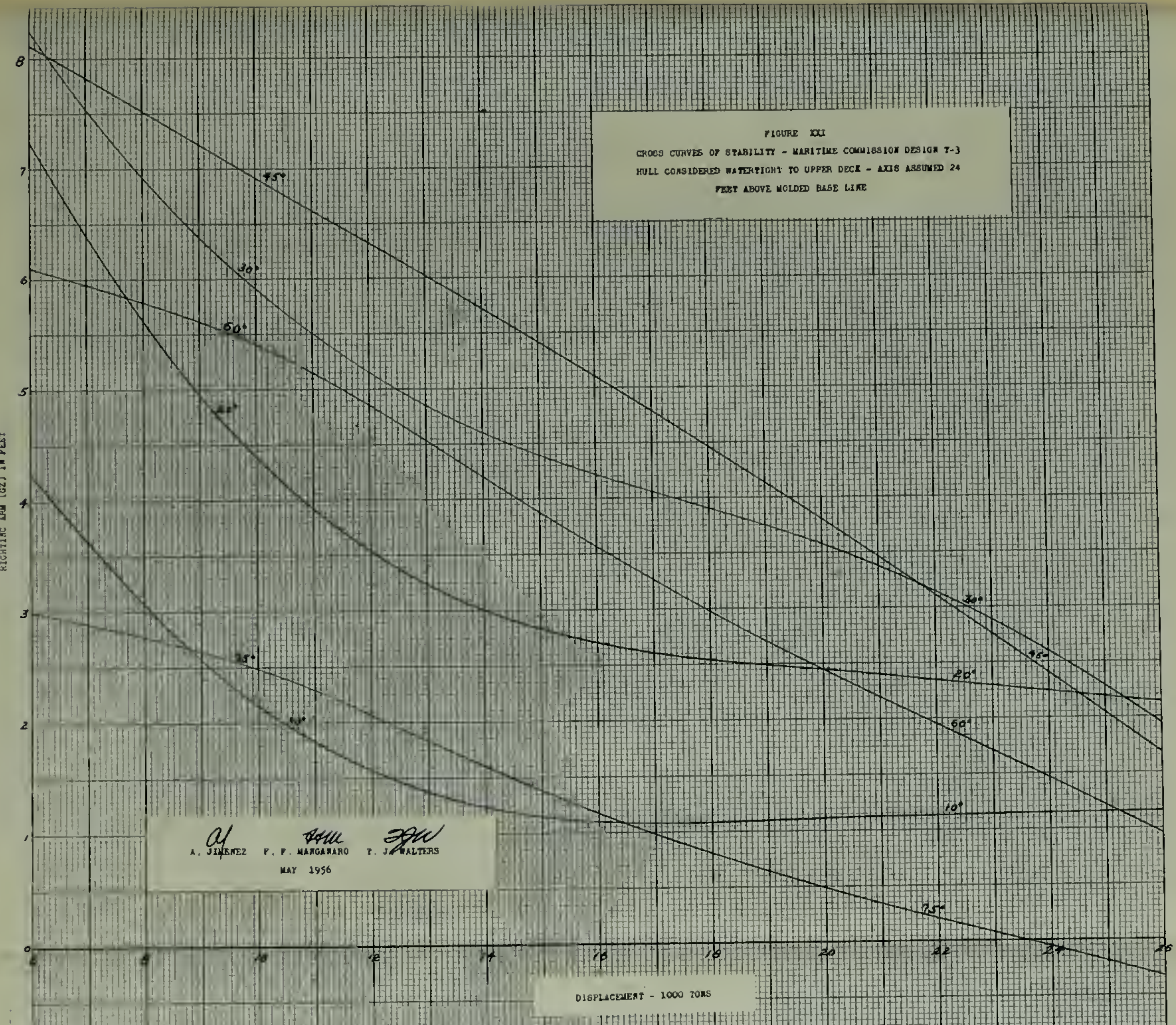

FIGURE XXI

CROSS CURVES OF STABILITY - MARITIME COMMISSION DESIGN T-3
HULL CONSIDERED WATERTIGHT TO UPPER DECK - AXIS ASSUMED 24
FEET ABOVE MOLDED BASE LINE

A. JIMENEZ F. F. MANGANARO T. J. WALTERS
MAY 1956

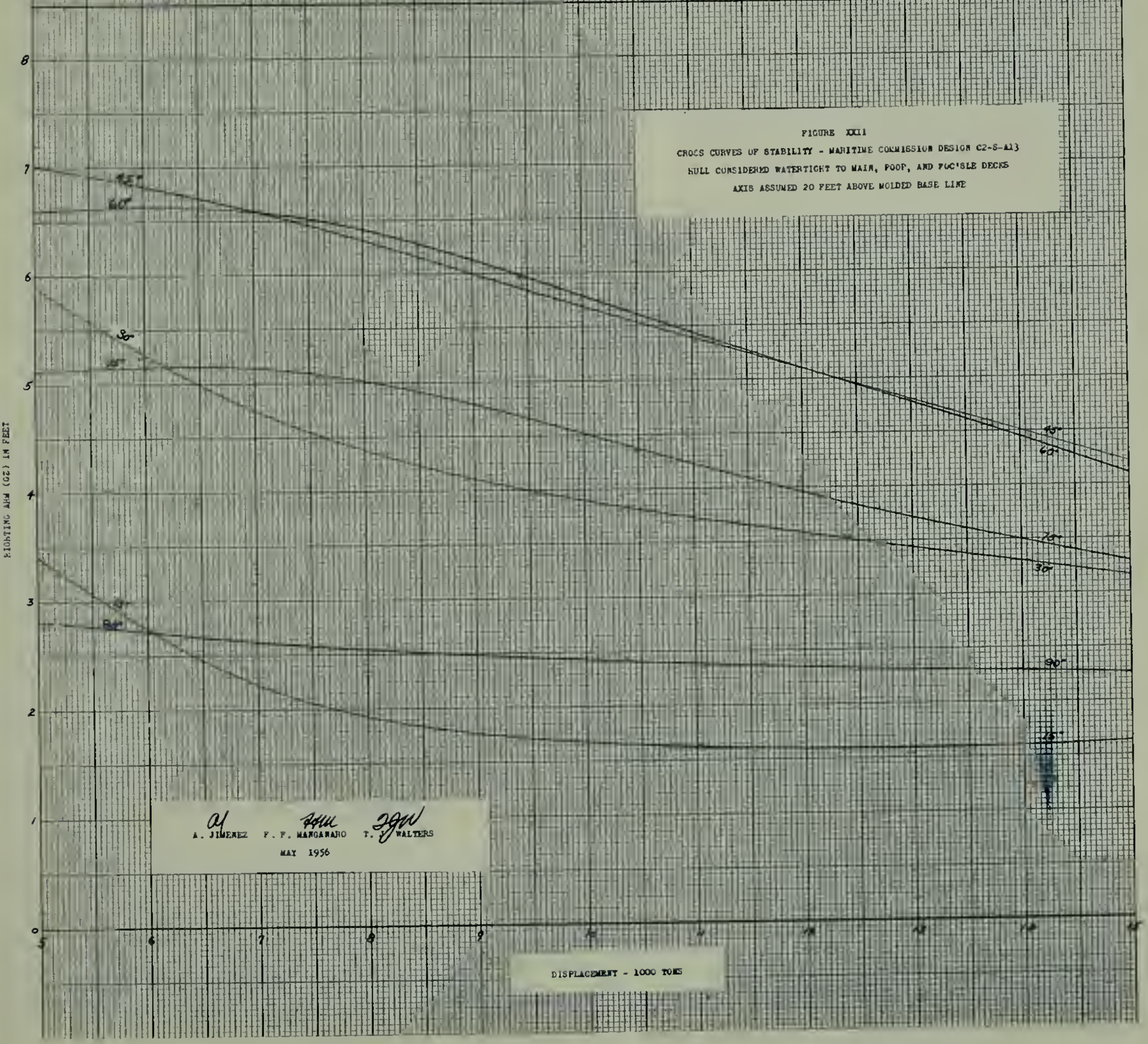

FIGURE XXII

CROCS CURVES OF STABILITY - MARITIME COMMISSION DESIGN C2-S-A13
HULL CONSIDERED WATERTIGHT TO MAIN, POOP, AND FOC'SLE DECKS
AXIS ASSUMED 20 FEET ABOVE MOLDED BASE LINE

A. JIMENEZ F. F. MANGANARO T. J. WALTERS
MAY 1956

TABLE V. DATA FOR SHIPS USED IN THE COMPARISON OF RESULTS

C1B	L	395.0	L/B	6.58	C_B	.689
	B	60.0	B/H	2.18	C_P	.696
	H	27.5	H/D	.734	C_X	.990
	D	37.5			C_W	.790
	Δ	12,875				
C1-M-AV1	L	320.0	L/B	6.40	C_B	.759
	B	50.0	B/H	2.78	C_P	.765
	H	18.0	H/D	.621	C_X	.9925
	D	29.0			C_W	.828
	Δ	6,279				
C2-S-A13	L	435	L/B	6.91	C_B	.682
	B	63	B/H	2.45	C_P	.698
	H	25.75	H/D	.635	C_X	.979
	D	40.5			C_W	.762
	Δ	13,862				
C3	L	465	L/B	6.59	C_B	.666
	B	69.5	B/H	2.44	C_P	.678
	H	28.5	H/D	.668	C_X	.981
	D	42.6			C_W	.776
	Δ	17,615				
ECZ-S-C1	L	416	L/B	7.32	C_B	.745
	B	56.9	B/H	2.34		
	H	24.37	H/D	.652		
	D	37.33				
	Δ	12,280				
VCZ-S- APZ	L	436.5	L/B	7.04	C_B	.6735
	B	62.0	B/H	2.22	C_P	.6818
	H	28.0	H/D	.737	C_X	.9879
	D	38.0			C_W	.7781
	Δ	14,832				
T-3	L	525	L/B	7.00	C_B	0.693
	B	75.0	B/H	2.56		
	H	29.3	H/D	0.75		
	D	39.0				
	Δ	22,600				
C4-S-1a	L	528			C_B	.624
(Mariner)	B	76	B/H =	2.54	C_P	.635
	H	29.833			C_X	.9825
	D	44.5	H/D =	.671	C_W	.7446
	Δ	21,089				

TABLE VI. FINAL TABULATION OF KZ AND KZ/B

$\theta = 10^\circ$

$C_b = 0.60$

H/D B/H	.60		.65		.70		.75		.80	
	KZ	KZ/B	KZ	KZ/B	KZ	KZ/B	KZ	KZ/B	KZ	KZ/B
2.00	.570	.067	.590	.069	.590	.069	.605	.071	.610	.071
2.34	.688	.069	.690	.069	.692	.069	.710	.071	.720	.072
2.50	.720	.067	.705	.066	.735	.069	.743	.070	.740	.069
2.75	.826	.070	.820	.070	.818	.070	.820	.070	.820	.070
3.00	.915	.071	.890	.070	.890	.070	.885	.069	.870	.068

$C_b = 0.70$

H/D B/H	.60		.65		.70		.75		.80	
	KZ	KZ/B	KZ	KZ/B	KZ	KZ/B	KZ	KZ/B	KZ	KZ/B
2.00	.570	.067	.590	.069	.595	.070	.600	.070	.600	.070
2.34	.700	.070	.718	.072	.710	.071	.700	.070	.700	.070
2.50	.765	.072	.770	.072	.750	.070	.742	.070	.740	.069
2.75	.870	.074	.848	.072	.820	.070	.820	.070	.800	.068
3.00	.960	.075	.935	.073	.890	.070	.890	.070	.860	.067

$C_b = 0.80$

H/D B/H	.60		.65		.70		.75		.80	
	KZ	KZ/B	KZ	KZ/B	KZ	KZ/B	KZ	KZ/B	KZ	KZ/B
2.00	.580	.068	.585	.068	.610	.071	.620	.073	.620	.073
2.34	.710	.071	.705	.070	.700	.070	.710	.071	.700	.070
2.50	.760	.071	.760	.071	.765	.072	.750	.070	.760	.071
2.75	.850	.072	.835	.071	.830	.071	.848	.072	.815	.069
3.00	.940	.073	.930	.073	.920	.072	.910	.071	.890	.070

TABLE VI. (continued)

$\theta = 20^\circ$

$C_b = 0.60$

B/H \ H/D	.60		.65		.70		.75		.80	
	KZ	KZ/B	KZ	KZ/B	KZ	KZ/B	KZ	KZ/B	KZ	KZ/B
2.00	1.184	.139	1.195	.140	1.202	.141	1.220	.143	1.230	.144
2.34	1.395	.139	1.400	.140	1.400	.140	1.400	.140	1.380	.138
2.50	1.518	.142	1.500	.140	1.485	.139	1.470	.138	1.460	.137
2.75	1.670	.142	1.665	.142	1.620	.138	1.600	.136	1.550	.132
3.00	1.884	.147	1.840	.144	1.782	.139	1.740	.136	1.650	.129

$C_b = 0.70$

B/H \ H/D	.60		.65		.70		.75		.80	
	KZ	KZ/B	KZ	KZ/B	KZ	KZ/B	KZ	KZ/B	KZ	KZ/B
2.00	1.200	.140	1.210	.142	1.220	.143	1.220	.143	1.220	.143
2.34	1.440	.144	1.430	.143	1.415	.142	1.400	.140	1.390	.139
2.50	1.550	.145	1.520	.142	1.515	.142	1.484	.139	1.460	.137
2.75	1.740	.148	1.710	.146	1.660	.141	1.620	.138	1.595	.136
3.00	1.940	.152	1.895	.148	1.830	.143	1.770	.138	1.700	.133

$C_b = 0.80$

B/H \ H/D	.60		.65		.70		.75		.80	
	KZ	KZ/B	KZ	KZ/B	KZ	KZ/B	KZ	KZ/B	KZ	KZ/B
2.00	1.185	.139	1.200	.140	1.220	.143	1.230	.144	1.225	.143
2.34	1.415	.141	1.420	.142	1.410	.141	1.410	.141	1.375	.138
2.50	1.535	.144	1.520	.142	1.510	.141	1.495	.140	1.460	.137
2.75	1.720	.146	1.690	.144	1.670	.142	1.640	.140	1.560	.133
3.00	1.930	.151	1.875	.146	1.860	.145	1.770	.138	1.680	.131

TABLE VI. (continued)

$\theta = 30^\circ$

$C_b = 0.60$

H/D B/H	.60		.65		.70		.75		.80	
	KZ	KZ/B	KZ	KZ/B	KZ	KZ/B	KZ	KZ/B	KZ	KZ/B
2.00	1.790	.210	1.810	.212	1.790	.210	1.790	.210	1.800	.211
2.34	2.090	.209	2.075	.208	2.045	.205	2.010	.201	1.955	.196
2.50	2.220	.208	2.220	.208	2.160	.202	2.100	.197	2.055	.192
2.75	2.440	.208	2.400	.204	2.318	.197	2.235	.190	2.160	.184
3.00	2.672	.209	2.610	.204	2.490	.194	2.398	.187	2.280	.178

$C_b = 0.70$

H/D B/H	.60		.65		.70		.75		.80	
	KZ	KZ/B	KZ	KZ/B	KZ	KZ/B	KZ	KZ/B	KZ	KZ/B
2.00	1.860	.218	1.850	.214	1.820	.213	1.820	.213	1.810	.212
2.34	2.160	.216	2.110	.211	2.070	.207	2.020	.202	1.982	.198
2.50	2.290	.214	2.240	.210	2.180	.204	2.140	.200	2.070	.194
2.75	2.530	.216	2.470	.210	2.360	.201	2.270	.193	2.210	.188
3.00	2.790	.218	2.675	.209	2.550	.199	2.420	.190	2.315	.181

$C_b = 0.80$

H/D B/H	.60		.65		.70		.75		.80	
	KZ	KZ/B	KZ	KZ/B	KZ	KZ/B	KZ	KZ/B	KZ	KZ/B
2.00	1.820	.213	1.810	.212	1.810	.212	1.800	.211	1.790	.210
2.34	2.150	.215	2.115	.211	2.060	.206	2.040	.204	1.970	.197
2.50	2.325	.218	2.255	.211	2.215	.208	2.160	.202	2.055	.192
2.75	2.615	.223	2.525	.215	2.450	.209	2.350	.200	2.215	.189
3.00	2.950	.230	2.800	.219	2.650	.207	2.510	.196	2.370	.185

TABLE VI. (continued)

$\theta = 40^{\circ}$

$C_b = 0.60$

H/D B/H	.60		.65		.70		.75		.80	
	KZ	KZ/B	KZ	KZ/B	KZ	KZ/B	KZ	KZ/B	KZ	KZ/B
2.00	2.330	.273	2.360	.276	2.310	.270	2.280	.267	2.270	.266
2.34	2.660	.266	2.620	.262	2.560	.256	2.505	.250	2.450	.245
2.50	2.780	.260	2.788	.261	2.680	.251	2.598	.243	2.510	.235
2.75	2.990	.255	2.930	.250	2.845	.242	2.730	.232	2.625	.224
3.00	3.192	.249	3.110	.243	2.992	.234	2.868	.224	2.750	.215

$C_b = 0.70$

H/D B/H	.60		.65		.70		.75		.80	
	KZ	KZ/B	KZ	KZ/B	KZ	KZ/B	KZ	KZ/B	KZ	KZ/B
2.00	2.430	.284	2.380	.279	2.350	.275	2.330	.273	2.310	.270
2.34	2.760	.276	2.680	.268	2.600	.260	2.530	.253	2.465	.246
2.50	2.890	.271	2.808	.263	2.710	.254	2.640	.247	2.550	.239
2.75	3.105	.264	3.005	.256	2.885	.246	2.770	.236	2.670	.227
3.00	3.328	.260	3.180	.248	3.055	.238	2.912	.227	2.780	.217

$C_b = 0.80$

H/D B/H	.60		.65		.70		.75		.80	
	KZ	KZ/B	KZ	KZ/B	KZ	KZ/B	KZ	KZ/B	KZ	KZ/B
2.00	2.430	.284	2.390	.280	2.340	.274	2.310	.270	2.270	.266
2.34	2.790	.279	2.700	.270	2.610	.261	2.545	.255	2.460	.246
2.50	2.990	.280	2.880	.270	2.775	.260	2.670	.250	2.550	.239
2.75	3.280	.279	3.145	.268	2.995	.255	2.872	.245	2.725	.232
3.00	3.530	.276	3.370	.263	3.140	.245	3.012	.235	2.888	.226

TABLE VI. (continued)

$\theta = 50^{\circ}$

$C_b = 0.60$

H/D B/H	.60		.65		.70		.75		.80	
	KZ	KZ/B	KZ	KZ/B	KZ	KZ/B	KZ	KZ/B	KZ	KZ/B
2.00	2.765	.324	2.780	.326	2.720	.318	2.680	.314	2.640	.309
2.34	3.052	.305	2.980	.298	2.940	.294	2.875	.288	2.815	.282
2.50	3.150	.295	3.122	.292	3.025	.283	2.950	.276	2.860	.268
2.75	3.328	.284	3.242	.276	3.175	.270	3.068	.261	2.950	.251
3.00	3.484	.272	3.394	.265	3.300	.258	3.170	.248	3.075	.240

$C_b = 0.70$

H/D B/H	.60		.65		.70		.75		.80	
	KZ	KZ/B	KZ	KZ/B	KZ	KZ/B	KZ	KZ/B	KZ	KZ/B
2.00	2.860	.335	2.815	.330	2.765	.324	2.720	.318	2.700	.316
2.34	3.145	.315	3.075	.308	2.985	.299	2.928	.293	2.845	.285
2.50	3.270	.306	3.190	.299	3.090	.290	3.000	.281	2.910	.273
2.75	3.440	.293	3.320	.283	3.235	.276	3.140	.268	3.020	.257
3.00	3.610	.282	3.465	.271	3.385	.264	3.258	.254	3.120	.244

$C_b = 0.80$

H/D B/H	.60		.65		.70		.75		.80	
	KZ	KZ/B	KZ	KZ/B	KZ	KZ/B	KZ	KZ/B	KZ	KZ/B
2.00	2.882	.337	2.840	.332	2.770	.324	2.725	.319	2.650	.310
2.34	3.195	.320	3.092	.309	2.995	.300	2.915	.292	2.830	.283
2.50	3.322	.311	3.230	.303	3.130	.292	3.012	.282	2.905	.272
2.75	3.535	.301	3.408	.290	3.290	.280	3.155	.269	3.040	.259
3.00	3.708	.290	3.590	.280	3.405	.266	3.280	.256	3.170	.248

TABLE VI. (continued)

$\theta = 60^\circ$

$C_b = 0.60$

H/D B/H	.60		.65		.70		.75		.80	
	KZ	KZ/B	KZ	KZ/B	KZ	KZ/B	KZ	KZ/B	KZ	KZ/B
2.00	3.050	.357	3.040	.356	2.995	.351	2.968	.348	2.920	.342
2.34	3.280	.328	3.200	.320	3.170	.317	3.120	.312	3.060	.306
2.50	3.352	.314	3.300	.309	3.232	.303	3.175	.297	3.100	.290
2.75	3.490	.297	3.410	.290	3.355	.286	3.270	.279	3.170	.270
3.00	3.630	.262	3.540	.276	3.470	.271	3.360	.262	3.275	.256

$C_b = 0.70$

H/D B/H	.60		.65		.70		.75		.80	
	KZ	KZ/B	KZ	KZ/B	KZ	KZ/B	KZ	KZ/B	KZ	KZ/B
2.00	3.135	.367	3.090	.362	3.065	.359	3.000	.351	2.990	.350
2.34	3.350	.335	3.295	.330	3.230	.323	3.180	.318	3.112	.311
2.50	3.455	.324	3.390	.318	3.308	.310	3.230	.303	3.160	.296
2.75	3.595	.306	3.480	.296	3.428	.292	3.352	.286	3.250	.277
3.00	3.715	.290	3.590	.280	3.530	.276	3.430	.268	3.330	.260

$C_b = 0.80$

H/D B/H	.60		.65		.70		.75		.80	
	KZ	KZ/B	KZ	KZ/B	KZ	KZ/B	KZ	KZ/B	KZ	KZ/B
2.00	3.170	.371	3.120	.365	3.050	.357	3.000	.351	2.930	.343
2.34	3.385	.339	3.295	.330	3.215	.322	3.145	.315	3.080	.308
2.50	3.460	.324	3.388	.317	3.300	.309	3.215	.301	3.125	.293
2.75	3.600	.307	3.495	.289	3.428	.292	3.310	.282	3.222	.274
3.00	3.730	.291	3.640	.284	3.520	.275	3.415	.267	3.312	.259

TABLE VI. (continued)

$\theta = 70^{\circ}$

$C_b = 0.60$

H/D B/H	.60		.65		.70		.75		.80	
	KZ	KZ/B	KZ	KZ/B	KZ	KZ/B	KZ	KZ/B	KZ	KZ/B
2.00	3.205	.375	3.200	.375	3.170	.371	3.145	.368	3.110	.364
2.34	3.375	.338	3.318	.332	3.280	.328	3.250	.325	3.208	.321
2.50	3.418	.320	3.378	.316	3.315	.311	3.285	.308	3.235	.303
2.75	3.505	.299	3.456	.294	3.410	.290	3.345	.285	3.290	.280
3.00	3.640	.284	3.580	.280	3.515	.274	3.448	.269	3.360	.262

$C_b = 0.70$

H/D B/H	.60		.65		.70		.75		.80	
	KZ	KZ/B	KZ	KZ/B	KZ	KZ/B	KZ	KZ/B	KZ	KZ/B
2.00	3.280	.334	3.240	.379	3.228	.378	3.175	.372	3.175	.372
2.34	3.420	.342	3.380	.338	3.332	.333	3.300	.330	3.260	.326
2.50	3.498	.328	3.440	.322	3.388	.317	3.340	.313	3.290	.308
2.75	3.600	.307	3.510	.299	3.475	.296	3.415	.291	3.350	.285
3.00	3.675	.287	3.580	.280	3.530	.276	3.468	.271	3.410	.266

$C_b = 0.80$

H/D B/H	.60		.65		.70		.75		.80	
	KZ	KZ/B	KZ	KZ/B	KZ	KZ/B	KZ	KZ/B	KZ	KZ/B
2.00	3.315	.388	3.260	.382	3.210	.376	3.155	.369	3.110	.364
2.34	3.420	.342	3.368	.337	3.308	.331	3.260	.326	3.215	.322
2.50	3.485	.326	3.420	.320	3.360	.315	3.298	.309	3.235	.303
2.75	3.555	.303	3.485	.297	3.440	.293	3.360	.286	3.302	.281
3.00	3.655	.285	3.600	.281	3.520	.275	3.440	.269	3.355	.262

TABLE VI. (continued)

$\theta = 80^\circ$

$C_b = 0.60$

H/D B/H	.60		.65		.70		.75		.80	
	KZ	KZ/B	KZ	KZ/B	KZ	KZ/B	KZ	KZ/B	KZ	KZ/B
2.00	3.255	.381	3.260	.382	3.245	.380	3.222	.377	3.210	.376
2.34	3.345	.335	3.330	.333	3.290	.329	3.275	.328	3.260	.326
2.50	3.372	.316	3.355	.314	3.305	.310	3.295	.309	3.280	.307
2.75	3.405	.290	3.395	.289	3.350	.285	3.322	.283	3.308	.282
3.00	3.488	.272	3.508	.274	3.435	.268	3.400	.266	3.330	.260

$C_b = 0.70$

H/D B/H	.60		.65		.70		.75		.80	
	KZ	KZ/B	KZ	KZ/B	KZ	KZ/B	KZ	KZ/B	KZ	KZ/B
2.00	3.308	.387	3.288	.373	3.272	.383	3.240	.379	3.250	.380
2.34	3.378	.338	3.350	.335	3.332	.333	3.310	.331	3.290	.329
2.50	3.420	.320	3.385	.317	3.360	.315	3.335	.312	3.308	.310
2.75	3.470	.296	3.425	.292	3.404	.290	3.370	.287	3.330	.284
3.00	3.510	.274	3.460	.270	3.420	.267	3.395	.265	3.365	.263

$C_b = 0.80$

H/D B/H	.60		.65		.70		.75		.80	
	KZ	KZ/B	KZ	KZ/B	KZ	KZ/B	KZ	KZ/B	KZ	KZ/B
2.00	3.320	.389	3.272	.383	3.240	.379	3.210	.376	3.190	.374
2.34	3.350	.335	3.325	.333	3.290	.329	3.260	.326	3.240	.324
2.50	3.390	.318	3.350	.314	3.310	.310	3.282	.308	3.250	.304
2.75	3.415	.291	3.380	.288	3.350	.285	3.305	.282	3.280	.279
3.00	3.472	.271	3.450	.269	3.408	.266	3.360	.262	3.310	.258

TABLE VI. (continued)

$\theta = 90^{\circ}$

$C_b = 0.60$

B/H \ H/D	.60		.65		.70		.75		.80	
	KZ	KZ/B	KZ	KZ/B	KZ	KZ/B	KZ	KZ/B	KZ	KZ/B
2.00	3.200	.375	3.216	.376	3.200	.375	3.210	.376	3.220	.377
2.34	3.200	.320	3.216	.321	3.200	.320	3.210	.321	3.220	.322
2.50	3.200	.300	3.216	.301	3.200	.300	3.210	.301	3.220	.302
2.75	3.200	.273	3.216	.274	3.200	.273	3.210	.273	3.220	.274
3.00	3.200	.250	3.216	.250	3.200	.250	3.210	.251	3.220	.251

$C_b = 0.70$

B/H \ H/D	.60		.65		.70		.75		.80	
	KZ	KZ/B	KZ	KZ/B	KZ	KZ/B	KZ	KZ/B	KZ	KZ/B
2.00	3.240	.379	3.238	.379	3.230	.378	3.220	.377	3.220	.377
2.34	3.240	.324	3.238	.324	3.230	.323	3.220	.322	3.220	.322
2.50	3.240	.304	3.238	.303	3.230	.303	3.220	.302	3.220	.302
2.75	3.240	.276	3.238	.276	3.230	.275	3.220	.274	3.220	.274
3.00	3.240	.253	3.238	.253	3.230	.252	3.220	.251	3.220	.251

$C_b = 0.80$

B/H \ H/D	.60		.65		.70		.75		.80	
	KZ	KZ/B	KZ	KZ/B	KZ	KZ/B	KZ	KZ/B	KZ	KZ/B
2.00	3.185	.373	3.180	.372	3.172	.371	3.170	.371	3.165	.371
2.34	3.185	.319	3.180	.318	3.172	.317	3.170	.317	3.165	.317
2.50	3.185	.298	3.180	.298	3.172	.297	3.170	.297	3.165	.296
2.75	3.185	.271	3.180	.271	3.172	.270	3.170	.270	3.165	.270
3.00	3.185	.249	3.180	.248	3.172	.248	3.170	.248	3.165	.247

TABLE VII.

PREDICTION OF STATICAL STABILITY BY METHOD OF HUBBARD AND THOMPSON

Ship USMC "VC2-S-AP2" C_p .682

B 62.0 D 38.0 H 28.0 S_f 4.0 S_a 6.0

Shear correction. - $D_c = \frac{S_f + S_a}{6} \cdot C_p + D = \frac{4+6}{6}(.692) + 38 = 39.15$

Corrected H/D .715 Corresp. C_p correction .976

Corrected C_p = (.682)(.976) = .665 Corr.D/B .631

Assumed KG used in cross-curves 20'

θ	KZ/B for D/B = .52 H/D .7	H/D .8	H/D .715	KZ/B for D/B = .64 H/D .7	H/D .8	H/D .715
15°	.114	.114	.114	.115	.118	.116
30°	.214	.197	.211	.222	.210	.220
45°	.265	.220	.258	.295	.276	.292
60°	.295	.277	.292	.341	.325	.339
75°	.300	.290	.299	.360	.349	.358
90°	.285	.285	.285	.350	.349	.350

θ	KZ/B for D/B = .631	KZ	KG sin θ	GZ
15°	.116	7.19	5.18	2.01
30°	.219	13.58	10.00	3.58
45°	.289	17.91	14.14	3.77
60°	.335	20.79	17.32	3.47
75°	.354	21.96	19.31	2.65
90°	.345	21.40	20.00	1.40

TABLE VII (cont.)

Prediction by Hubbard and Thompson

Ship USMC C1-M-AV1 C_p = .765

B = 50.0 D = 29.0 H = 18.0 S_f = 5 S_a = 3

Shear correction. $D_c = \frac{S_f + S_a}{6} C_p + D = \frac{5+3}{6}(.765) + 29.0 = 30.0$

Corrected H/D = .60 Corresp. C_p correction 1.009

Corrected C_p = (.765)(1.009) = .772 Corr. D/B = .60

Assumed KG = 18.0

	D/B= 0.52	0.64	0.60	KZ	KG sin θ	GZ
θ	H/D= 0.6	0.6	KZ/B			
15°	.120	.117	.118	5.90	4.66	1.24
30°	.230	.230	.230	11.50	9.00	2.50
45°	.291	.315	.307	15.35	12.72	2.63
60°	.315	.358	.344	17.20	15.59	1.61
75°	.311	.370	.350	17.50	17.38	.12
90°	.284	.345	.325	16.25	18.00	−1.75

Ship USMC C4-S-1a (Mariner) C_p = .635

B = 76.0 D = 44.5 H = 29.833 S_f = 11.0 S_a = 3.5

Shear correction. $D_c = \frac{S_f + S_a}{6} C_p + D = \frac{11 + 3.5}{6}(.635) + 44.5 = 46.0$

Corr. H/D = .65 Corresp. C_p correction .992

Corr. C_p = (.635)(.992) = .630 Corr. D/B = .606 Assumed KG = 28.0

D/B	.52			.64			.606			
θ H/D	.60	.70	.65	.60	.70	.65	KZ/B	KZ	KG sin θ	GZ
15°	.111	.112	.112	.113	.115	.114	.113	8.58	7.24	1.34
30°	.223	.214	.219	.225	.222	.223	.222	16.88	14.00	2.88
45°	.288	.266	.277	.308	.296	.302	.294	22.36	19.80	2.56
60°	.317	.295	.306	.355	.342	.348	.334	25.40	24.22	1.18

TABLE VII (Continued)

Ship USMC EC2-S-C1 C_p = .76

B = 56.9 D = 37.33 H = 24.37 S_f = 9.2 S_a = 5.2

Shear correction. $D_c = \frac{S_f + S_a}{6} C_p + D = \frac{9.2+5.2}{6}(.76) + 37.33 = 39.15$

Corr. H/D = .623 Corresp. C_p correction 1.001

Corr. C_p = (.76)(1.001) = .762 Corr.D/B = .688 Assumed KG = 21

	D/B = .64			D/B = .90			D/B=.688	KZ	KGsinθ	GZ
θ H/D	.60	.70	.623	.60	.70	.623				
15°	.116	.118	.116	.115	.127	.118	.116	6.60	5.43	1.17
30°	.230	.223	.231	.242	.250	.244	.233	13.27	10.50	2.77
45°	.314	.295	.309	.352	.353	.352	.317	18.02	14.84	3.18
60°	.358	.338	.353	.435	.425	.432	.367	20.87	18.18	2.69
75°	.370	.355	.366	.480	.473	.478	.387	22.00	20.30	1.70
90°	.320	.344	.326	.485	.482	.484	.355	20.20	21.00	-.80

Ship USMC C3 C_p = .678

B = 69.5 D - 42.6 H = 28.5 S_f = 12.0 S_a = 6.5

Shear correction. $D_c = \frac{S_f + S_a}{6} C_p + D = \frac{12+6.5}{6}(.678) + 42.6 = 44.69$

Corr. H/D = .638 Corresp. C_p correction .996

Corr. C_p = (.678)(.996) = .675 Corr.D/B = .643 Assumed KG = 24

	D/B = .64			D/B = .90			D/B=.643	KZ	KGsinθ	GZ
θ H/D	.60	.70	.638	.60	.70	.638				
15°	.114	.115	.114	.115	.123	.118	.114	7.91	6.22	1.69
30°	.227	.222	.225	.239	.250	.243	.225	15.63	12.00	3.63
45°	.310	.295	.304	.350	.353	.351	.305	21.20	16.97	4.23
60°	.356	.340	.350	.435	.432	.434	.351	24.40	20.78	3.62
75°	.373	.360	.368	.484	.477	.481	.369	25.62	23.20	2.42
90°	.352	.349	.350	.493	.490	.492	.352	24.46	24.00	.46

TABLE VII (cont.)

Ship USMC C1B C_p = .696

B = 60.0 D = 37.5 H = 27.5 S_f = 8.6 S_a = 4.2

Shear correction. $D_c = \frac{S_f + S_a}{6} C_p + D = \frac{8.6 + 4.2}{6}(.696) + 37.5 = 38.99$

Corr.H/D = .705 Corresp. C_p correction = .978

Corr. C_p = (.696)(.978) = .680 Corr.D/B = .65 Assumed KG = 21'

	D/B = .64			D/B = .90			D/B = .65	KZ	KGsinθ	GZ
θ H/D	.70	.80	.705	.70	.80	.705				
15°	.115	.120	.115	.124	.140	.125	.115	6.90	5.43	1.47
30°	.222	.210	.221	.250	.259	.250	.222	13.32	10.50	2.82
45°	.295	.275	.294	.353	.355	.353	.297	17.82	14.84	2.98
60°	.340	.323	.339	.430	.430	.430	.343	20.59	18.18	2.41
75°	.359	.347	.358	.477	.472	.477	.363	21.80	20.30	1.50
90°	.350	.347	.350	.488	.487	.488	.355	21.30	21.00	.30

Ship USMC C2-S-B1 C_p = .698

B = 63.0 D = 40.5 H = 25.75 S_f = 9.5 S_a = 6.0

Shear correction. $D_c = \frac{S_f + S_a}{6} C_p + D = \frac{9.5 + 6.0}{6}(.698) + 40.5 = 42.3$

Corr.H/D = .608 Corresp. C_p correction = 1.006

Corr. C_p = (.698)(1.006) = .702 Corr.D/B = .672 Assumed KG = 20'

	D/B = .64			D/B = .90			D/B = .672			
θ H/D	.60	.70	.608	.60	.70	.608		KZ	KGsinθ	GZ
15°	.115	.116	.115	.115	.124	.116	.115	7.24	5.18	2.06
30°	.228	.223	.228	.240	.250	.241	.229	14.43	10.00	4.43
45°	.311	.295	.310	.350	.352	.350	.315	19.83	14.14	5.69
60°	.356	.340	.355	.435	.430	.435	.365	23.00	17.32	5.68
75°	.372	.358	.371	.482	.476	.482	.393	24.76	19.31	5.45
90°	.350	.348	.350	.490	.487	.490	.378	23.80	20.00	3.80

TABLE VII (cont.)

Ship USMC T-3 C_p = .702

B = 75.0 D = 39' H = 29.3 S_f = 8 S_a = 4

Shear correction. $D_c = \frac{S_f + S_a}{6} C_p + D = \frac{8+4}{6}(.702) + 39 = 40.4$

Corr. H/D = .726 Corresp. C_p correction .973

Corr. C_p = (.702)(.973) = .683 Corr.D/B = .538 Assumed KG = 24

	D/B = .52			D/B = .64			D/B = .538			
θ H/D	.70	.80	.726	.70	.80	.726		KZ	KGsinθ	GZ
15°	.115	.115	.115	.115	.119	.116	.115	8.62	6.22	2.40
30°	.215	.197	.211	.222	.210	.219	.212	15.90	12.00	3.90
45°	.265	.245	.260	.295	.275	.290	.264	19.80	16.97	2.83
60°	.294	.275	.289	.340	.324	.336	.296	22.20	20.78	1.42
75°	.298	.288	.296	.360	.348	.357	.305	22.88	23.20	-.32
90°	.285	.283	.285	.349	.348	.349	.295	22.14	24.00	-1.86

TABLE VIII.

PREDICTION OF STATICAL STABILITY FROM OUR CURVES (UNCORRECTED)

Ship USMC "VC2-S-AP2" C_b .6735

B 62.0 D 38.0 H 28.0 B/H 2.22 H/D .737

Assumed KG used in cross-curves 20'

θ	KZ/B			KZ	KG sin θ	GZ
	C_b .6	C_b .7	C_b .6735			
10°	.070	.070	.070	4.34	3.47	.87
20°	.140	.141	.141	8.74	6.84	1.90
30°	.205	.207	.207	12.84	10.00	2.84
40°	.258	.261	.260	16.13	12.87	3.26
50°	.298	.304	.302	18.72	15.32	3.40
60°	.327	.330	.329	20.40	17.32	3.08
70°	.341	.346	.345	21.40	18.80	2.60
80°	.346	.348	.347	21.50	19.70	1.80
90°	.339	.341	.340	21.08	20.00	1.08

Ship USMC "C1-M-AV1" C_b = .759

B 50.0 D 29.0 H 18.0 B.H 2.78 H/D .621

Assumed KG in cross-curves 18'

θ	KZ/B			KZ	KG sin θ	GZ
	C_b .6	C_b .7	C_b .6735			
10°	.073	.077	.075	3.75	3.13	.62
20°	.147	.146	.146	7.30	6.16	1.14
30°	.213	.222	.218	10.90	9.00	1.90
40°	.259	.277	.270	13.50	11.58	1.92
50°	.287	.297	.293	14.65	13.78	.87
60°	.301	.303	.302	15.10	15.58	-.48
70°	.301	.300	.300	15.00	16.90	-1.90
80°	.291	.287	.289	14.45	17.70	-3.25
90°	.272	.268	.270	13.50	18.00	-4.50

TABLE VIII (cont.)

Ship USMC C4-S-1a (Mariner) C_b = .624

B 76.0 D 44.5 H 29.333 B/H 2.54 H/D .671

Assumed KG in cross-curves 28.0

θ	KZ/B			KZ	KG sin θ	GZ
	C_b .6	C_b .7	C_b .624			
10°	.070	.071	.070	5.32	4.86	.46
20°	.139	.143	.140	10.64	9.57	1.07
30°	.203	.207	.204	15.50	14.00	1.50
40°	.253	.257	.254	19.30	18.00	1.30
50°	.285	.292	.286	21.75	21.43	.32
60°	.304	.311	.306	23.24	24.22	
70°	.310	.316	.312	23.74	26.32	
80°	.308	.312	.309	23.50	27.58	
90°	.296	.298	.296	22.50	28.00	

Ship USMC EC2-S-C1 C_b = .745

B 56.9 D 37.33 H 24.37 B/H 2.34 H/D .625

Assumed KG used in cross-curves 21'

θ	KZ/B			KZ	KG sin θ	GZ
	C_b .7	C_b .8	C_b .745			
10°	.070	.070	.070	3.98	3.64	.34
20°	.142	.143	.142	8.07	7.18	.89
30°	.213	.213	.213	12.12	10.50	1.62
40°	.270	.276	.273	15.52	13.50	2.02
50°	.312	.317	.314	17.87	16.08	1.79
60°	.333	.334	.333	18.94	18.18	.76
70°	.340	.340	.340	19.35	19.72	-.37
80°	.337	.335	.336	19.12	20.66	-1.54
90°	.324	.318	.321	18.26	21.00	-2.74

TABLE VIII (cont.)

Ship USMC "C-3" C_b = .666

B 69.5 D 42.0 H 28.5 B/H 2.44 H/D .668

Assumed KG used in cross curves 24'

θ	KZ/B			KZ	KG sin θ	GZ
	C_b .6	C_b .7	C_b .666			
10°	.070	.070	.070	4.86	4.16	.70
20°	.139	.142	.141	9.80	8.21	1.59
30°	.204	.208	.207	14.40	12.00	2.40
40°	.255	.261	.259	18.00	15.42	2.58
50°	.289	.298	.295	20.50	18.38	2.12
60°	.312	.319	.317	22.06	20.80	1.26
70°	.320	.326	.324	22.54	22.57	-.03
80°	.320	.322	.321	22.30	23.62	-1.32
90°	.308	.310	.309	21.48	24.00	-2.52

Ship USMC C1B C_b = .689

B 60.0 D 37.5 H 27.5 B/H 2.18 H/D .734

Assumed KG used in cross curves 21'

θ	KZ/B			KZ	KG sin θ	GZ
	C_b .6	C_b .7	C_b .689			
10°	.070	.069	.069	4.14	3.64	.50
20°	.141	.141	.141	8.45	7.18	1.27
30°	.207	.209	.209	12.55	10.50	2.05
40°	.260	.264	.264	15.84	13.50	2.34
50°	.302	.309	.308	18.48	16.08	2.40
60°	.329	.337	.336	20.18	18.18	2.00
70°	.345	.351	.350	21.00	19.72	1.28
80°	.351	.354	.354	21.22	20.66	.56
90°	.345	.347	.347	20.82	21.00	-.18

TABLE VIII (cont.)

Ship USMC C2-S-B1 C_b = .682

B 63.0 D 40.5 H 25.75 B/H 2.45 H/D .635

Assumed KG used in cross curves 20'

θ	KZ/B			KZ	KG sin θ	GZ
	C_b .6	C_b .7	C_b .682			
10°	.069	.071	.071	4.47	3.47	1.00
20°	.140	.143	.143	9.00	6.84	2.16
30°	.207	.212	.211	13.30	10.00	3.30
40°	.261	.266	.265	16.70	12.87	3.83
50°	.283	.305	.301	18.96	15.32	3.64
60°	.315	.324	.322	20.28	17.32	2.96
70°	.323	.329	.328	20.66	18.80	1.86
80°	.321	.324	.323	20.36	19.70	.66
90°	.308	.309	.309	19.48	20.00	-.52

Ship USMC T-3 C_b = .693

B 75.0 D 39' H 29.3 B/H 2.56 H/D .750

Assumed KG used in cross curves 24'

θ	KZ/B			KZ	KG sin θ	GZ
	C_b .6	C_b .7	C_b .693			
10°	.070	.070	.070	5.25	4.16	1.09
20°	.138	.139	.139	10.42	8.21	2.21
30°	.195	.198	.198	14.85	12.00	2.85
40°	.240	.242	.242	18.15	15.42	2.73
50°	.273	.278	.278	20.82	18.38	2.44
60°	.293	.299	.299	22.42	20.80	1.62
70°	.302	.307	.307	23.02	22.57	.45
80°	.303	.307	.307	23.02	23.62	-.60
90°	.293	.295	.295	22.14	24.00	-1.86

Calculation of Points by the Method of Ref. 42 (Bureau of Ships).

As mentioned in Section IV, Ref. 42 allows the prediction of GZ at a few angles. Where the H/D fell within the permissible range, or just outside, the following calculations were done and the points plotted as circled asterisks in Figures XI and XII.

C1-B

$C_b = .689 \quad H/B = .458 \quad H/D = .734 \quad F/B = 10/60 = .167$

20° $H/B = .45$

$OZ/B = .0086 \quad OZ = .0086 \times 60 = .516$

$KO = 0.4B = 24$

$KG = 21$

$OG \sin\theta = 3 \sin 20^\circ = 1.026$

$GZ = OZ + OG \sin\theta = .516 + 1.026 = 1.542$

30°

H/B	.45	.50	.458
OZ/B	.015	.0182	.0155

$OZ = .0155 \times 60 = .93$

$3 \sin 30^\circ = \underline{1.50}$

$GZ = 2.43$

C1-M-AV1

$C_b = .759 \quad H/B = .36 \quad F/B = 11/50 = .22$

20°

H/B	.35	.40	.36
OZ/B	.010	.008	.0096

$OZ = .0096 \times 50 = .48$

$KO = 0.4B = 0.4 \times 50 = 20$

$KG = 18$

$OG \sin\theta = 2 \sin 20^\circ = .684$

$GZ = .480 + .684 = 1.164$

C1-M-AV1 (continued)

30° H/B .35 .40 .36

OZ/B = .0260 .0190 .0246

OZ = .0246 x 50 = 1.23

2 sin 30° = 1.00

GZ = 2.23

C-2

C_b = .682 H/B = .408 F/B = 14.75/63 = .234

20° H/B .40 .45 .408

OZ/B = .0080 .0088 .0082

OZ = .0082 x 63 = .516

KO = 0.4B = 0.4 x 63 = 25.2

KG = 20

5.2 sin 20° = 1.78

GZ = 1.78 + .516 = 2.296

30° H/B .40 .45 .408

OZ/B = .019 .018 .0188

OZ = .0188 x 63 = 1.184

5.2 sin 30° = 2.600

GZ = 3.784

EC2-S-C1

C_b = .745 H/B = .427 F/B = 12.96/56.9 = .228

20° H/B .40 .45 .427

OZ/B .008 .0086 .0083

OZ = .0083 x 56.9 = .472

KO = .4(56.9) = 22.76

KG = 21

1.76 sin 20° = .602

GZ = .472 + .602 = 1.074

EC2-S-C1 (continued)

30°	H/B	.40	.45	.427
	OZ/B	.0194	.0190	.0192

OZ = .0192 x 56.9 = 1.092

1.76 sin 30° = .880

GZ = 1.972

C4-S-1a Mariner

C_b = .624 H/B = .394 F/B = 14.7/76 = 0.1935

20° OZ/B = .0108 OZ = 76 x .0108 = .82

OK = .4(76) = 30.4

KG = 28

2.4 sin 20° = .82

GZ = 1.64

30° OZ/B = .0190 OZ = 76 x .0190 = 1.443

2.4 sin 30° = 1.200

GZ = 2.643

VC-2

C_b = .6735 H/B = .45 F/B = 10/62 = .1613

20° OZ/B = .009 OZ = .009 x 62 = .558

KG = 20

KO = .4 x 62 = 24.8

OG sin θ = 4.8 sin 20° = 1.642

GZ = OZ + OG sin θ = 2.200

30° OZ/B = .015 OZ = .015 x 62 = .93

4.8 sin 30° = 2.40

3.33

40° OZ = .024 OZ = .024 x 62 = 1.488

4.8 sin 40° = 3.090

GZ = 4.578

C-3

C_b = .666   H/B = .41   F/B = 14.1/69.5 = .203

20° H/B .40 .45 .41

OZ/B .0082 .0094 .00844

OZ = .00844 x 69.5 = .586

KO = .4 x 69.5 = 27.8

KG = 24

3.8 sin 20° = 1.300

GZ = 1.886

30° H/B .40 .45 .41

OZ/B .0164 .0160 .01632

OZ = .01632 x 69.5 = 1.135

3.8 sin 30° = 1.9

GZ = 3.035

T-3

C_b = .693   H/B = .391   F/B = 9.7/75 = .1293

20° H/B .35 .40 .391

OZ/B .0094 .0080 .0083

OZ = .0083 x 75 = .622

KO = 0.4x75 = 30

6 sin 20° = 2.052

KG = 24

GZ = 2.674

30° OZ/B = .016   OZ = .016 x 75 = 1.20

6 sin 30° = 3.00

GZ = 4.20

APPENDIX D. SAMPLE CALCULATIONS

For Volume of Displacement and Stability arm KZ for Hull 11 at 45° up to 1"WL, S = Station Spacing = 7.5"

From Table X

$f(A) = 8301 \qquad f(M) = 12{,}989$

$\Delta_1 = 2S/3\,[f(A)]\,[\text{Integrator Const. for area}]$

$\Delta_1 = 2(7.5)/3\,[8301]\,[1/49.55] = 837.57 \text{ inches}^3$

$KZ_1 = 2/3\,S[f(M)/f(A)]\left[\dfrac{\text{integrator const. for moment}}{\text{integrator const. for area}}\right]$

$KZ_1 = 2/3\,(7.5)\,[12{,}989/8{,}301]\,[49.55/24.89] =$

$5(1.5648)(49.55/24.89)$

$KZ_1 = 3.1152 \text{ inches}$

For the slice 1" to 2"

$f(A) = 4{,}766 \qquad f(M) = 6{,}309$

$\Delta_{12} = 2S/3\,[f(A)][\text{integrator const. for area}]$

$\Delta_{12} = 2(7.5)/3\,[4{,}766]\,[1/49.55] = 480.89 \text{ inches}^3$

$\Delta_2 = \Delta_1 + \Delta_{12} = 837.57 + 480.89 = 1{,}318.46 \text{ inches}^3$

$\sum f(A) = 8{,}301 + 4{,}766 = 13{,}067$

$\sum f(M) = 12{,}989 + 6{,}309 = 19{,}298$

$KZ_2 = 2/3\,(7.5)[19{,}298/13{,}067]\,[49.55/24.89] = 2.940 \text{ inches}$

Identical calculations were carried out for each sheet of integrated data. Table X and Table XI are samples. A summary of all such work is in Appendix F.

Table XII is a sample of the data which results from the lateral expansion. Figure XXIII is a sample of the graphical process used to get such data. As this method is completely graphical the only calculation that is required is for the corresponding angles. This is given in Table IX.

TABLE IX. CORRESPONDING ANGLES FOR THE LATERAL EXPANSION

$$\text{tangent } \theta_2 = \frac{1}{C} \text{ tangent } \theta_1$$

θ_1	Tanθ_1	tangent θ_2				θ_2			
		12,32, 52	13,33, 53	14,34, 54	15,35, 55	12,32, 52	13,33, 53	14,34, 54	15,35, 55
10°	0.1763	.1377	.1652	.2064	.1502	$7^\circ 50'$	$9^\circ 23'$	$11^\circ 40'$	$8^\circ 34'$
20°	0.3640	.2844	.3411	.4262	.3101	$15^\circ 53'$	$18^\circ 50'$	$23^\circ 05'$	$17^\circ 14'$
30°	0.5774	.4511	.5411	.6761	.4918	$24^\circ 17'$	$28^\circ 25'$	$34^\circ 04'$	$26^\circ 11'$
45°	1.0000	.7812	.9372	1.1710	.8518	$38^\circ 00'$	$43^\circ 09'$	$49^\circ 30'$	$40^\circ 26'$
60°	1.7321	1.3532	1.6233	2.0282	1.4754	$53^\circ 32'$	$58^\circ 22'$	$63^\circ 45'$	$55^\circ 52'$
75°	3.7321	2.9157	3.4978	4.3701	3.1790	$71^\circ 04'$	$74^\circ 03'$	$77^\circ 07'$	$72^\circ 32'$

TABLE X. INTEGRATION FOR KZ

AREAS AND MOMENTS OF INCLINED SECTIONS

Hull No. 11 | WL = Up to 1"
Integrator #2 | Axis through G, KG - 0".0 | θ = 45°

Station	Start	Finish	Diff.	S.M.	f(A)	Start	Finish	Diff.	S.M.	f(M)
0	0	0	0	1/4	0	0	0	0	1/4	0
½	1664 1710	1710 1754	46 44	1	45	9419 9404	9404 9391	15 13	1	14
1	1754 1858	1858 1962	104 104	3/4	78	9391 9344	9344 9300	47 44	3/4	34
2	1962 2291	2291 2619	329 328	2	657	9300 8990	8990 8679	310 311	2	621
3	2619 3310	3310 4003	691 693	1	692	8679 7665	7665 6642	1014 1013	1	1014
4	4003 4928	4928 5857	925 929	2	1854	6642 5053	5053 3465	1589 1588	2	3177
5	5857 6839	6839 7823	982 984	1	983	3465 1767	1767 0065	1698 1702	1	1700
6	7823 8786	8786 9746	963 960	2	1923	0065 1438	8386 9783	1679 1655	2	3334
7	9746 0581	0581 1419	835 838	1	836	6578 9783	5169 8370	1409 1413	1	1411
8	1419 2127	1970 2673	551 546	2	1097	3535 2393	2721 1581	814 812	2	1626
9	2673 2795	2795 2917	122 122	3/4	92	1581 1519	1519 1465	62 54	3/4	44
9½	2917 2961	2961 3004	44 43	1	44	1465 1450	1450 1438	15 12	1	14
10			0	1/4	0			0	1/4	0
			Σ_1	=	8301 1.5648			Σ_1	=	12989

Δ_1 = 837.57

KZ_1 = 3.1152

TABLE X. (cont.)

AREAS AND MOMENTS OF INCLINED SECTIONS

Hull No. 11 WL = 1" to 2"
Integrator #2 Axis through G, KG = 0".0 θ = 45°

Station	Start	Finish	Diff.	S.M.	f(A)	Start	Finish	Diff.	S.M.	f(M)
0			0	1/4	0			0	1/4	0
½	4896 4955	4955 5015	59 60	1	60	7987 7940	7940 7893	47 47	1	47
1	5015 5151	5151 5285	136 134	3/4	101	7893 7787	7787 7673	106 114	3/4	82
2	1088 1410	1410 1732	322 322	2	644	9922 9525	9525 9128	397 397	2	794
3	1732 2153	2153 2574	421 421	1	421	9128 8530	8530 7935	598 595	1	596
4	6679 7095	7095 7506	416 411	2	828	5660 5119	5119 4579	541 540	2	1081
5	7506 7910	7910 8316	404 406	1	405	4579 4061	4061 3541	518 520	1	519
6	7506 7910	7910 8316	405	2	810			519	2	1038
7	8316 8729	8729 9138	413 409	1	411	3541 3000	3000 2456	541 544	1	542
8	9435 9838	9838 0237	403 399	2	802	2206 1610	1610 1009	596 601	2	1197
9	0372 0667	0667 0965	295 298	3/4	222	0993 0507	0507 0020	486 487	3/4	364
9½	0965 1027	1027 1088	62 61	1	62	0020 9973	9973 9922	47 51	1	49
10			0	1/4	0			0	1/4	0

Σ_{12} = 4766 1.4768 Σ_{12} = 6309

Σ_{2} = 13067 Σ_{2} = 19298

Δ_{12} = 480.89 Δ_{2} = 1,318.46

KZ = 2.9400

TABLE X. (cont.)

AREAS AND MOMENTS OF INCLINED SECTIONS

Hull No. 11
Integrator #2 Axis through G, KG = 0". WL = 2" to 3"
$\theta = 45^\circ$

Station	Start	Finish	Diff.	S.M.	f(A)	Start	Finish	Diff.	S.M.	f(M)
0			0	1/4	0			0	1/4	0
½	2937	3004	67	1	66	7534	7450	84	1	86
	3004	3068	64			7450	7362	88		
1	3068	3223	155	3/4	117	7362	7154	208	3/4	155
	3223	3380	157			7154	6947	207		
2	0730	1083	353	2	706	7928	7405	523	2	1037
	4196	4549	353			5694	5180	514		
3	4549	4942	393	1	392	5180	4756	424	1	428
	4942	5333	391			4756	4324	432		
4	5333	5736	403	2	807	4324	3973	351	2	708
	5736	6140	404			3973	3616	357		
5	6140	6544	404	1	404	3616	3292	324	1	324
	6544	6948	404			3292	2967	325		
6	6948	7344	396	2	792	2967	2635	332	2	660
	7344	7740	396			2635	2307	328		
7	7740	8125	385	1	385	2307	1938	369	1	368
	1083	1468	385			7405	7038	367		
8	1468	1810	342	2	688	1565	1124	441	2	886
	8854	9200	346			1124	0679	445		
9	9200	9472	272	3/4	206	0679	0192	487	3/4	367
	9472	9747	275			0192	9701	491		
9½	9747	9985	238	1	236	9701	9229	472	1	478
	9985	0219	234			9229	8745	484		
10	0177	0200	23	1/4	6	8458	8409	49	1/4	12
	0200	0225	25			8409	8360	49		

Σ_{23} = 4805 1.3880 Σ_{23} = 5509

Σ_3 = 17872 Σ_3 = 24807

Δ_{23} = 484.82 Δ_3 = 1,803.28

KZ = 2.7632

TABLE X. (cont.)

AREAS AND MOMENTS OF INCLINED SECTIONS

Hull No. 11 WL = 3" to 4"
Integrator #2 Axis through G, KG = 0".0 θ = 45°

Station	Start	Finish	Diff.	S.M.	f(A)	Start	Finish	Diff.	S.M.	f(M)
	2112	2114	2	1/4	1	5635	5627	8	1/4	2
0	2114	2120	6			5627	5622	5		
½	9807	9694	87	1	86	7080	6922	152	1	154
	9694	9779	85			6922	6765	157		
1	2555	2735	180	3/4	136	4828	4486	342	3/4	257
	2735	2918	183			4486	4142	344		
2	3703	3977	274	2	550	2814	2439	375	2	753
	4179	4455	276			2225	1847	378		
3	4455	4790	335	1	336	1847	1564	283	1	284
	4790	5127	337			1564	1278	286		
4	5127	5488	361	2	723	1278	1069	209	2	421
	5488	5850	362			1069	0857	212		
5	5850	6221	371	1	371	0857	0686	171	1	168
	6221	6592	371			0686	0512	164		
6	6592	6952	360	2	720	0512	0323	189	2	375
	6952	7312	360			0323	0137	186		
7	7312	7649	337	1	334	0137	9898	239	1	240
	7649	7980	331			9898	9656	242		
8	7980	8259	279			9656	9347	309	2	614
	8259	8538	279	2	558	9347	9042	305		
9	8538	8748	210	3/4	158	9042	8700	342	3/4	254
	8748	8959	211			8700	8364	336		
9½	8959	9137	178	1	176	8364	8034	330	1	331
	9137	9312	175			8034	7702	332		
10	9312	9459	147	1/4	37	7702	7390	312	1/4	78
	9459	9607	148			7390	7080	310		

Σ_{34} = 4186 1.2983 Σ_{134} = 3831

Σ_4 = 22058 Σ_4 = 28638

Δ_{34} = 422.37 Δ_4 = 2,225.65

KZ = 2.5846

TABLE X. (cont.)

AREAS AND MOMENTS OF INCLINED SECTIONS

Hull No. 11 | WL = 4" to 5"
Integrator #2 | Axis through G, KG = 0".0 | θ = 45°

Station	Start	Finish	Diff.	S.M.	f(A)	Start	Finish	Diff.	S.M.	f(A)
0	9694	9718	24	1/4	5	6381	6327	54	1/4	13
	9718	9737	19			6327	6274	53		
½	9737	9831	94	1	94	6274	6066	208	1	206
	9831	9925	94			6066	5862	204		
1	9925	0041	116	3/4	87	5862	5638	224	3/4	170
	4622	4739	117			1975	1746	229		
2	0160	0348	188	2	380	5402	5155	247	2	492
	0348	0540	192			5155	4910	245		
3	0540	0800	260	1	262	4910	4717	193	1	190
	0800	1064	264			4717	4530	187		
4	1064	1360	296	2	592	4530	4412	118	2	236
	1360	1656	296			4412	4294	118		
5	1656	1961	305	1	304	4294	4203	91	1	92
	1961	2264	303			4203	4110	93		
6	2264	2562	298	2	600	4110	4008	102	2	200
	2562	2864	302			4008	3910	98		
7	2864	3132	268	1	269	3910	3764	146	1	146
	3132	3402	270			3764	3618	146		
8	3402	3620	218	2	435	3618	3420	198	2	394
	4739	4956	217			1746	1550	196		
9	3852	4006	154	3/4	117	3187	2972	215		162
	4006	4165	159			2972	2755	217	3/4	
9½	4165	4296	131	1	132	2755	2548	207	1	209
	4296	4428	132			2548	2337	211		
10	4428	4525	97	1/4	24	2337	2155	182	1/4	45
	4525	4622	97			2155	1975	180		
			Σ_{45}	=	3301	1.2300		Σ_{45}	=	2555

Σ_5 = 25359 | Σ_5 = 31193

Δ_{45} = 333.07 | Δ_5 = 2,558.72

KZ = 2.4487

TABLE XI. INTEGRATION FOR ZB

AREAS AND MOMENTS OF INCLINED SECTIONS

Hull No. 11 WL = Up to 0"
Integrator #2 Axis through G, KG = 0". $\theta = 45^\circ$

Station	Start	Finish	Diff.	S.M.	f(A)	Start	Finish	Diff.	S.M.	f(M)
0	0	0	0	1/4	0	0	0	0	1/4	0
½	5480	5482	2	1	2	1619	1617	2	1	0
	5482	5483	1			1617	1619	-2		
1	5483	5491	8	3/4	7	1619	1620	-1	3/4	-1
	5491	5500	9			1620	1621	-1		
2	5500	5605	105	2	200	1621	1637	-16	2	-37
	5605	5700	95			1637	1658	-21		
3	5700	6045	345	1	344	1658	1784	-26	1	-28
	6045	6387	342			1784	1914	-30		
4	6387	6917	530	2	1070	1914	2187	-273	2	-546
	6917	7457	540			2187	2460	-273		
5	7457	8045	588	1	586	2460	2791	-331	1	-329
	8045	8628	583			2791	3118	-327		
6	8628	9188	560	2	1120	3118	3418	-300	2	-599
	9188	9748	560			3418	3717	-299		
7	9748	0187	439	1	436	3717	3899	-182	1	-182
	0187	0619	432			3899	4080	-181		
8	0619	0794	175	2	346	4080	4116	-36	2	-70
	0794	0965	171			4116	4150	-34		
9	0965	0975	10	3/4	8	4150	4153	-3	3/4	-2
	0975	0985	10			4153	4154	-1		
9½	Same as ½		2	1	2	Same as ½		0	1	0
10	0	0	0	1/4	0		0	0	1/4	0
			Σ_0	=	4121	-0.4353		Σ_0	=	-1794

Δ_0 = 415.81

ZB = -0.8666

TABLE XI. (cont.)

AREAS AND MOMENTS OF INCLINED SECTIONS

Hull No. 11
Integrator #2

WL = 0" to 1"
θ = 45°

Axis through G, KG = 0".

Station	Start	Finish	Diff.	S.M.	f(A)	Start	Finish	Diff.	S.M.	f(M)
0	0	0	0	1/4	0	0	0	0	1/4	0
½	1523 1479	1571 1523	48 44	1	48	4003 4017	3992 4003	11 14	1	12
1	1571 1669	1669 1764	98 95	3/4	72	3992 3967	3967 3938	25 29	3/4	20
2	1764 2000	2000 2227	236 227	2	463	3938 3879	3879 3817	59 62	2	120
3	2227 2571	2571 2916	344 345	1	344	3817 3726	3726 3635	91 91	1	91
4	2916 3310	3310 3698	394 388	2	782	3635 3536	3536 3438	99 98	2	197
5	3698 4082	4082 4478	384 396	1	390	3438 3346	3346 3247	92 99	1	96
6	4478 4478	4478 4478	390	2	780	3247 3247	3247 3247	96	2	192
7	4478 4872	4872 5261	394 389	1	391	3247 3147	3147 3049	100 98	1	99
8	5261 5630	5630 6996	369 366	2	735	3049 2951	2951 2855	98 96	2	194
9	6996 6110	6110 6221	114 111	3/4	84	2855 2825	2825 2793	30 32	3/4	23
9½	6221 6264	6264 6310	43 46	1	45	2793 2780	2780 2768	13 12	1	12
10	0	0	0	1/4	0	0	0	0	1/4	0

Σ_{01} = 4134 -0.0894 Σ_{01} = 1056

Σ_{1} = 8255 Σ_{1} = -738

Δ_{01} = 417.12 Δ_{1} = 832.93

ZB = -0.1780

TABLE XI. (cont.)

AREAS AND MOMENTS OF INCLINED SECTIONS

Hull No. 11
Integrator #2

WL = 1" to 2"
$\theta = 45^{\circ}$

Axis through G, KG = 0".

Station	Start	Finish	Diff.	S.M.	f(A)	Start	Finish	Diff.	S.M.	f(M)
0	0	0	0	1/4	0	0	0	0	1/4	0
½	6522	6581	59	1	60	3123	3075	48	1	46
	6581	6643	62			3075	3032	43		
1	6643	6782	139	3/4	104	3032	2927	105	3/4	78
	6782	6920	138			2927	2823	104		
2	6920	7240	320	2	641	2823	2581	242	2	485
	7240	7561	321			2581	2338	243		
3	7561	7980	419	1	418	2338	2026	312	1	311
	7980	8397	417			2026	1716	310		
4	8397	8809	412	2	831	1716	1408	308	2	616
	8809	9228	419			1408	1100	308		
5	9228	9632	404	1	408	1100	0795	305	1	304
	9632	0045	413			0795	0491	304		
6	9632	0045	408	2	816	0795	0491	304	2	608
7	0045	0450	405	1	408	0491	0187	304	1	308
	0450	0860	410			0187	9875	312		
8	0860	1262	402	2	801	9875	9584	291	2	589
	1262	1661	399			9584	9286	298		
9	1661	1960	299	3/4	225	9286	9056	230	3/4	173
	1960	2262	302			9056	8824	232		
9½	2262	2335	73	1	74	8824	8771	53	1	47
	2335	2409	74			8771	8710	41		
10	0	0	0	1/4	0	0	0	0	1/4	0

Σ_{12} = 4786 0.2160 Σ_{12} = 3555

Σ_{2} = 13041 Σ_{2} = 2817

Δ_{12} = 482.91 Δ_{2} = 1315.84

ZB = 0.4300

TABLE XI. (cont.)

AREAS AND MOMENTS OF INCLINED SECTIONS

Hull No. 11
Integrator #2

WL = 2" to 3"
θ = 45°

Axis through G, KG = 0".

Sta-tion	Start	Finish	Diff.	S.M.	f(A)	Start	Finish	Diff,	S.M.	f(M)
0	0	0	0	1/4	0	0	0	0	1/4	0
½	1950 2015	2015 2082	65 67	1	66	9402 9318	9318 9236	84 82	1	83
1	2082 2241	2241 2400	159 159	3/4	119	9236 9037	9037 8838	199 199	3/4	149
2	2400 2750	2750 3104	350 354	2	704	8838 8400	8400 7968	438 432	2	870
3	3104 3490	3490 3878	386 388	1	387	7968 7483	7483 6998	485 485	1	485
4	3878 4282	4282 4682	404 400	2	804	6998 6502	6502 6002	496 500	2	996
5	4682 5087	5087 5491	405 404	1	404	6002 5498	5498 4997	504 501	1	502
6	5491 5891	5891 6291	400 400	2	800	4997 4505	4505 4005	492 500	2	992
7	6291 6675	6675 7059	384 384	1	384	4005 3526	3526 3054	479 472	1	476
8	7059 7400	7400 7741	341 341	2	682	3054 2631	2631 2208	423 423	2	846
9	7741 8017	8017 8288	276 271	3/4	206	2208 1867	1867 1532	341 335	3/4	254
9½	8288 8522	8522 8757	234 235	1	234	1532 1241	1241 0948	291 293	1	292
10	8757 8784	8784 8810	27 26	1/4	7	0948 0914	0914 0873	34 41	1.4	9

Σ_{23} = 4797 0.4917 Σ_{23} = 5954

Σ_3 = 17838 Σ_3 = 8771

Δ_{23} = 484.02 Δ_3 = 1799.85

ZB = 0.9789

TABLE XI. (cont.)

AREAS AND MOMENTS OF INCLINED SECTIONS

Hull No. 11
Integrator #2

WL = 3" to 5"
$\theta = 45^\circ$

Axis through G, KG = 0".0

Station	Start	Finish	Diff.	S.M.	f(A)	Start	Finish	Diff.	S.M.	f(M)
0	9655	9682	27	1/4	7	9803	9745	58	1/4	15
	9682	9708	26			9745	9685	60		
½	9708	9886	178	1	180	9685	9323	362	1	360
	9886	0067	181			9323	8966	357		
1	0067	1368	301	3/4	226	8966	8385	581	3/4	435
	0368	0670	302			8385	7808	577		
2	0670	1137	467	2	936	7808	6907	901	2	1806
	1137	1606	469			6907	6002	905		
3	1606	2206	600	1	602	6002	4829	1173	1	1176
	2206	2810	604			4829	3649	1180		
4	2810	3474	664	2	1325	3649	2351	1298	2	2601
	3474	4135	661			2351	1048	1303		
5	4135	4815	680	1	680	1048	9714	1334	1	1334
	7054	7734	680			0270	8935	1335		
6	7734	8399	665	2	1328	8935	7633	1302	2	2602
	8399	9062	663			7633	6333	1300		
7	9062	9669	607	1	606	6333	5147	1186	1	1188
	9669	0273	604			5147	3958	1189		
8	0273	0773	500	2	1000	3958	2985	973	2	1945
	0773	1273	500			2985	2013	972		
9	1273	1640	367	3/4	273	2013	1305	708	3/4	531
	1640	2003	363			1305	0598	707		
9½	2003	2310	307	1	307	0598	0006	592	1	594
	2310	2617	307			0006	9410	596		
10	2617	2860	243	1/4	61	9410	8941	469	1/4	118
	2860	3105	245			8941	8470	471		
			Σ_{35}	=	7531	0.9254		Σ_{35}	=	14705

Σ_5 = 25369 $\qquad$ Σ_5 = 23476

Δ_{35} = 759.88 $\qquad$ Δ_5 = 2559.73

ZB = 1.8423

TABLE XII.

RESULTS OF THE LATERAL EXPANSION OF HULL 51 to HULLS 52, 53, 54, 55

Hull			10°		20°		30°	
	Δ	λ	SB	KZ	SB	KZ	SB	KZ
51	800.0	1.000	1.769	1.900	1.792	2.032	2.358	2.685
52	1024.0	1.280	2.264	2.372	2.294	2.481	3.018	3.275
53	853.6	1.067	1.888	2.011	1.912	2.140	2.516	2.820
54	683.2	0.854	1.510	1.669	1.530	1.811	2.014	2.400
55	939.2	1.174	2.077	2.190	2.104	2.312	2.768	3.060
51	1400.0	1.000	0.550	0.756	1.136	1.548	1.720	2.345
52	1792.0	1.280	0.704	0.871	1.454	1.780	2.202	2.720
53	1493.8	1.067	0.587	0.785	1.212	1.600	1.835	2.430
54	1195.6	0.854	0.469	0.739	0.970	1.447	1.469	2.200
55	1643.6	1.174	0.646	0.825	1.333	1.697	2.019	2.580
51	1900.0	1.000	0.430	0.711	0.875	1.426	1.370	2.188
52	2432.0	1.280	0.551	0.777	1.120	1.555	1.754	2.420
53	2027.3	1.067	0.459	0.735	0.934	1.455	1.462	2.240
54	1622.6	0.854	0.367	0.690	0.747	1.377	1.170	2.100
55	2230.6	1.174	0.505	0.750	1.028	1.502	1.608	2.330
51	2500.0	1.000	0.355	0.704	0.697	1.411	0.990	2.038
52	3200.0	1.280	0.454	0.721	0.892	1.455	1.267	2.124
53	2667.5	1.067	0.379	0.735	0.743	1.420	1.056	2.054
54	2135.0	0.854	0.303	0.748	0.595	1.415	0.845	2.030
55	2935.0	1.174	0.417	0.726	0.818	1.439	1.162	2.092
51	3100.0	1.000	0.284	0.730	0.457	1.330	0.586	1.856
52	3968.0	1.280	0.363	0.721	0.586	1.282	0.750	1.800
53	3307.7	1.067	0.303	0.735	0.488	1.312	0.625	1.840
54	2647.4	0.854	0.242	0.769	0.395	1.377	0.500	1.940
55	3639.4	1.174	0.334	0.726	0.537	1.300	0.688	1.810

Table XII. (cont.)

Hull	Δ	λ	45° SB	45° KZ	60° SB	60° KZ	75° SB	75° KZ
51	800.0	1.000	4.200	3.710	3.400	3.665	3.561	3.575
52	1024.0	1.280	5.376	4.864	4.352	4.404	4.558	4.070
53	853.6	1.067	4.481	3.980	3.628	3.830	3.799	3.678
54	683.2	0.854	3,587	3.120	2.904	3.320	3.041	3.350
55	939.2	1.174	4.931	4.420	3.992	4.120	4.180	3.870
51	1400.0	1.000	2.956	3.260	2.788	3.574	2.775	3.425
52	1792.0	1.280	3.784	3.986	3.569	4.180	3.552	3.810
53	1493.8	1.067	3.154	3.430	2.975	3.730	2.961	3.500
54	1195.6	0.854	2.524	2.890	2.381	3.350	2.370	3.260
55	1643.6	1.174	3.470	3.718	3.273	3.960	3.258	3.645
51	1900.0	1.000	2.300	3.076	2.132	3.425	2.178	3.337
52	2432.0	1.280	2.944	3.564	2.729	3.810	2.788	3.620
53	2027.3	1.067	2.454	3.190	2.275	3.500	2.324	3.390
54	1622.6	0.854	1.964	2.830	1.821	3.270	1.860	3.220
55	2230.6	1.174	2.700	3.386	2.503	3.664	2.557	3.500
51	2500.0	1.000	1.590	2.784	1.460	3.176	1.511	3.219
52	3200.0	1.280	2.035	3.025	1.869	3.380	1.934	3.498
53	2667.5	1.067	1.697	2.840	1.558	3.216	1.612	3.348
54	2135.0	0.854	1.358	2.660	1.247	3.096	1.290	3.250
55	2935.0	1.174	1.867	2.950	1.714	3.300	1.774	3.420
51	3100.0	1.000	0.920	2.498	0.800	2.925	0.791	3.088
52	3968.0	1.280	1.178	2.518	1.024	2.960	1.012	3.150
53	3307.7	1.067	0.982	2.500	0.854	2.930	0.844	3.095
54	2647.4	0.854	0.786	2.490	0.683	2.914	0.675	3.053
55	3639.4	1.174	1.080	2.510	0.939	2.950	0.928	3.120

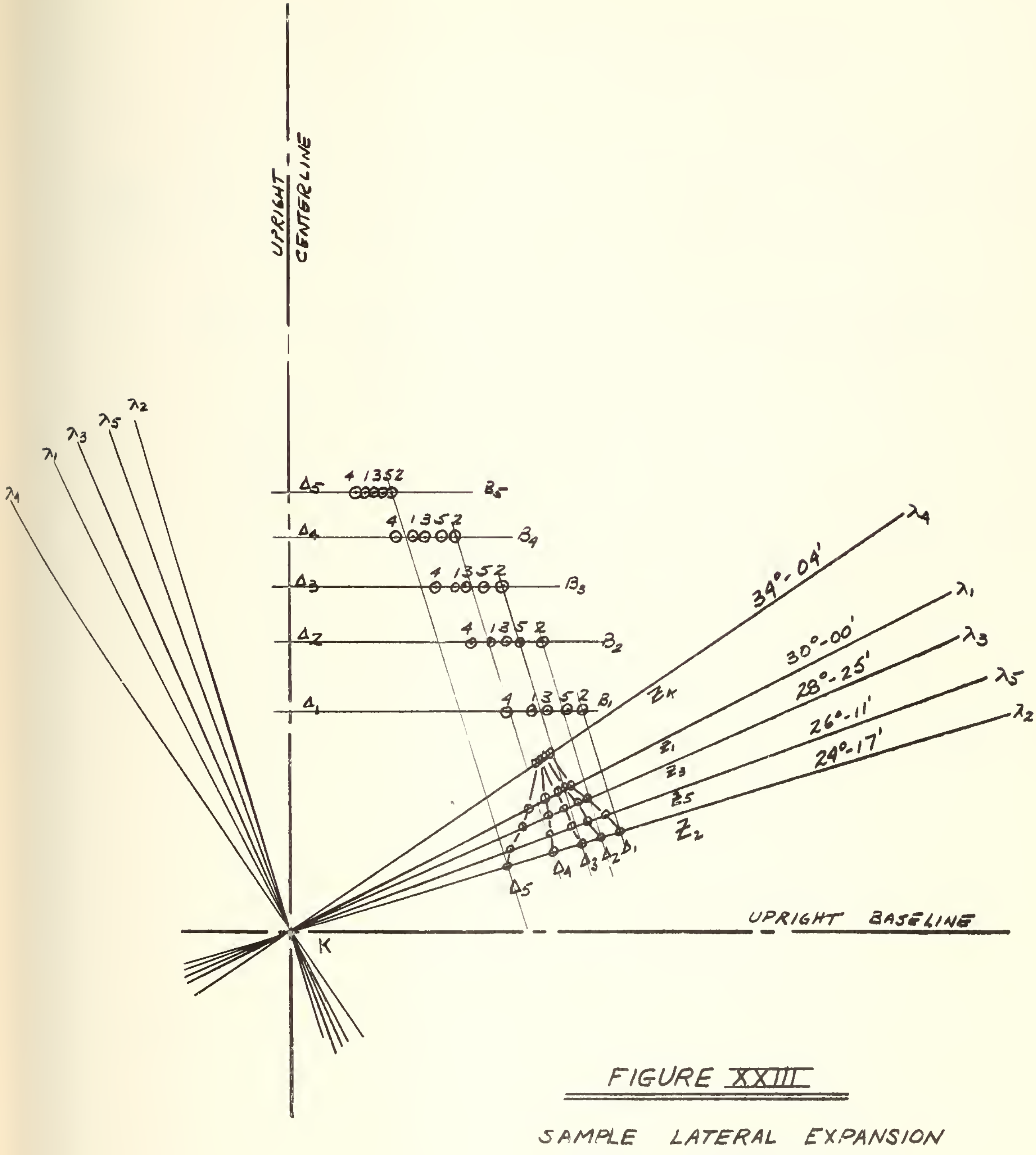
UPRIGHT CENTERLINE
λ4
λ1
λ3
λ5
λ2
Δ5 4 1352 B5
Δ4 4 1352 B4
Δ3 4 1352 B3
Δ2 4 135 2 B2
Δ1 4 135 2 B1
λ4
34°-04'
λ1
30°-00'
λ3
28°-25'
λ5
26°-11'
λ2
24°-17'
Z_K
Z1
Z3
Z5
Z2
Δ5 Δ4 Δ3 Δ2 Δ1
UPRIGHT BASELINE
K

FIGURE XXIII

SAMPLE LATERAL EXPANSION
30° - SCHEMATIC ONLY
HULLS 11-12-13-14-15 $C_b = 0.60$

APPENDIX E. SUPPLEMENTARY DISCUSSION

The following table is published to illustrate further the point made at the end of Section III, Results, that the effect on GZ of small variations in KZ/B is considerable.

TABLE XIII. SENSITIVITY OF GZ TO VARIATIONS IN KZ/B

θ	Diff. in GZ	Reg'd diff. in KZ/B	Ship
30°	.38	.00633	
40°	.56	.00933	
50°	.56	.00933	
60°	.72	.01200	
70°	.82	.01365	C1B
80°	.72	.01200	
90°	.60	.01000	
30°	.63	.0111	
40°	1.00	.0176	
50°	1.58	.0278	
60°	2.24	.0394	
70°	2.62	.0460	EC2-S-C1
80°	2.85	.0500	
90°	3.08	.0541	
30°	.98	.0141	
40°	1.54	.0221	
50°	2.13	.0306	
60°	2.58	.0371	C3
70°	2.94	.0423	
80°	3.15	.0453	
90°	3.27	.0470	

APPENDIX F. ORIGINAL DATA

This Appendix contains:

1. A summary of the integration data, (Tables XIV and XV). The actual work sheets with the integrator readings were too numerous to publish. These along with the body plans and other data and work sheets too numerous to publish have been turned over to Professor Manning for the use of future investigators.

2. The cross-curves of stability for the three parent models, Figure XXIV through Figure XXVI.

3. Curves of KZ vs. θ for various B/H values at constant C_B and H/D ratio are included as Figures XXVII through XLI.

4. Displacement vs. Draft curves for the three parents, Figure XLII.

5. KB vs. Draft curves for the three parents, Figure XLIII.

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4. Displacement vs. Draft curves for the three parents, Figure XLII.

5. KB vs. Draft curves for the three parents, Figure XLIII.

TABLE XIV. RESULTS OF INTEGRATION FOR KZ

HULL NO. 11

KG = 0 for all angles. Asterisk indicates integrator #1 was used. All other readings with integrator #2.

$\theta = 10^\circ$

WL	f(A) Slice	f(A) Total	f(M) Slice	f(M) Total	Tot.f(M) / Tot.f(A)	Total displ.	KZ (in.)
Up to 0"	405	405	543	543	1.3407	40.82	2.6999*
Up to $\frac{1}{2}$"	1768	1768	1444	1444	.8167	178.21	1.6447*
Up to 1"	3735	3735	2045	2045	.5475	376.86	1.0900
1" to 2"	4340	8075	1134	3179	.3937	814.77	.7838
2" to 3"	4821	12896	1316	4495	.3486	1301.20	.6940
3" to 4"	5106	18002	1820	6315	.3508	1816.40	.6984
4" to 5"	5467	23469	2423	8738	.3723	2368.02	.7412
$\theta = 20^\circ$							
Up to 1"	4336	4336	4101	4101	.9458	437.50	1.8829
1" to 2"	4476	8812	2538	6639	.7534	889.13	1.4999
2" to 3"	5039	13851	3041	9680	.6989	1397.56	1.3914
3" to 4"	5424	19275	4013	13693	.7104	1944.85	1.4143
4" to 5"	4895	24170	2731	16424	.6795	2438.75	1.3527
$\theta = 30^\circ$							
Up to 1"	5479	5479	6590	6590	1.2028	552.83	2.3945
1" to 2"	4505	9984	4279	10869	1.0886	1007.38	2.1672
2" to 3"	5303	15287	5104	15973	1.0449	1542.46	2.0802
3" to 4"	5040	20327	4101	20074	.9876	2050.99	1.9661
4" to 5"	4061	24388	2240	22314	.9150	2460.75	1.8216
$\theta = 45^\circ$							
Up to-2"	316	316	560	560	1.7722	31.85	3.5688*
Up to-1"	1566	1566	2676	2676	1.7088	157.85	3.4412*
Up to 0"	4128	4128	6871	6871	1.6645	416.10	3.3520*
Up to 1"	8301	8301	12989	12989	1.5648	837.57	3.1152
1" to 2"	4766	13067	6309	19289	1.4768	1318.46	2.9400
2" to 3"	4805	17872	5509	24807	1.3880	1803.28	2.7632
3" to 4"	4186	22058	3831	28638	1.2983	2225.65	2.5846
4" to 5"	3301	25359	2555	31193	1.2300	2558.72	2.4487
$\theta = 60^\circ$							
Up to -1"	3889	3889	7154	7154	1.8395	392.40	3.6621
-1" to 1"	7881	11770	12722	19876	1.6887	1187.59	3.3619
1" to 2"	4412	16182	6065	25941	1.6031	1632.76	3.1914
2" to 3"	4003	20185	5108	31049	1.5382	2036.67	3.0622
3" to 5"	6066	26251	6342	37391	1.4244	2648.72	2.8357

TABLE XIV (cont.)

HULL NO. 11 (cont.)

KG = 0 for all angles. Asterisk indicates integrator #1 was used. All other readings with integrator #2.

WL	f(A) Slice	f(A) Total	f(M) Slice	f(M) Total	Tot.f(M) / Tot.f(A)	Total displ.	KZ (in.)
$\theta = 75^\circ$							
Up to -4"	138	138	185	185	1.3406	13.91	2.6997*
Up to -3"	1494	1494	2705	2705	1.8106	150.60	3.6462*
Up to -2"	3858	3858	7251	7251	1.8795	389.27	3.7417
Up to -1"	6891	6891	12631	12631	1.8329	694.61	3.6911
-2" to 0"	6961	10819	11734	18985	1.7548	1091.64	3.4934
0" to 2"	8368	19187	12577	31562	1.6450	1935.97	3.2749
2" to 3"	3468	22655	4899	36461	1.6094	2285.89	3.2040
3" to 4"	2821	25476	3814	40275	1.5809	2570.53	3.1472
$\theta = 90^\circ$							
Up to 3"	6825	6825	11555	11555	1.6930	687.96	3.4094*
3" to 4½"	5474	12299	8793	20348	1.6544	1239.74	3.3316*
4½" to 6"	6127	18426	9778	30126	1.6349	1857.34	3.2924*

HULL NO. 31

KG = 0 for all angles except 45° where KG $\sin\theta$ = 1"
Integrator #1 used.

$\theta = 10^\circ$							
Up to 1"	4487	4487	2999	2999	.6684	452.29	1.3460
1" to 2"	5056	9543	1118	4117	.4314	961.93	.8688
2" to 3"	5429	14972	1436	5553	.3709	1509.18	.7469
3" to 4"	5585	20557	2040	7593	.3694	2072.14	.7439
4" to 5"	5949	26506	2673	10266	.3873	2671.80	.7790
$\theta = 20^\circ$							
Up to 1"	5342	5342	5654	5654	1.0584	538.47	2.1314
1" to 2"	5105	10447	2794	8448	.8086	1053.06	1.6284
2" to 3"	5719	16166	3263	11711	.7244	1629.53	1.4588
3" to 4"	5962	22128	4380	16091	.6957	2232.72	1.4010
4" to 5"	5334	27462	2886	18977	.6667	2770.92	1.3426
$\theta = 30^\circ$							
Up to 2½"	--	14839	16047	16047	1.0814	1495.77	2.1777
Up to 3½"	--	20927	21318	21318	1.0187	2109.44	2.0514
3½" to 4½"	5201	26128	3455	24773	0.9481	2633.70	1.9093
$\theta = 45^\circ$							
Up to 0"	5384	5384	6308	6308	1.1716	542.71	3.3594
0" to 1"	4615	9999	4948	11256	1.1257	1007.90	3.2669
1" to 2"	5179	15178	4393	15649	1.0310	1529.94	3.0762
2" to 3"	5175	20353	2838	18487	.9083	2051.58	2.8291
3" to 5"	8434	28787	1946	20433	.7098	2901.73	2.4294

TABLE XIV (cont.)

HULL NO. 31. (cont.)

KG = 0 for all angles except 45° where KG sin θ = 1"
Integrator #1 used.

WL	f(A) Slice	f(A) Total	f(M) Slice	f(M) Total	$\frac{\text{Tot.f(M)}}{\text{Tot.f(A)}}$	Total displ.	KZ (in.)
$\theta = 60^\circ$							
Up to -1"	4914	4914	9024	9024	1.8364	495.33	3.6981
-1" to 1"	8625	13539	14430	23454	1.7323	1364.73	3.4885
1" to 2"	4668	18207	6394	29848	1.6394	1835.26	3.3014
2" to 3"	4421	22628	5315	35163	1.5540	2280.90	3.1294
3" to 5"	7119	29747	6219	41318	1.3911	2998.50	2.8014
$\theta = 75^\circ$							
Up to 0"	---	13164	22775	22775	1.7301	1326.93	3.4841
Up to 1"	---	17518	29625	29625	1.6911	1765.81	3.4055
1" to 2½"	6191	23709	9039	38664	1.6308	2389.87	3.2841
$\theta = 90^\circ$							
Up to 3"	8417	8417	13705	13705	1.6282	848.43	3.2789
3" to 4½"	5992	14409	9567	23272	1.6151	1452.43	3.2525
4½" to 6"	6352	20761	10002	33274	1.6027	2092.71	3.2275

HULL NO. 51

KG = 0 for all angles except 45° and 60°, where KG sin θ = 1". Asterisk indicates Integrator #1 was used; all other readings with integrator #2.

WL	f(A) Slice	f(A) Total	f(M) Slice	f(M) Total	$\frac{\text{Tot.f(M)}}{\text{Tot.f(A)}}$	Total displ.	KZ (in.)
$\theta = 10^\circ$							
Up to 1"	5564	5564	3720	3720	.6686	561.41	1.3310
1" to 2"	6048	11612	1136	4856	.4182	1171.65	.8326
2" to 3"	6305	17917	1573	6429	.3588	1807.83	.7143
3" to 4"	6493	24410	2195	8624	.3533	2462.97	.7033
4" to 5"	6734	31144	2813	11437	.3672	3142.43	.7310
$\theta = 20^\circ$							
Up to 1"	6347	6347	7104	7104	1.1193	640.41	2.2283
1" to 2"	5925	12272	2972	10076	.8211	1238.24	1.6346
2" to 3"	6552	18824	3401	13477	.7159	1899.34	1.4252
3" to 4"	6836	25660	4682	18159	.7077	2589.09	1.4089
4" to 5"	5995	31655	2633	20792	.6568	3193.99	1.3076
$\theta = 30^\circ$							
Up to 1"	7869	7869	10631	10631	1.3510	793.98	2.6896
1" to 2"	5892	13761	5612	16243	1.1804	1388.48	2.3499
2" to 3"	6911	20672	5998	22241	1.0759	2085.80	2.1419
3" to 4"	6357	27029	4572	26813	.9920	2727.23	1.9749
4" to 5"	5039	32068	2312	29125	.9082	3253.66	1.8080

TABLE XIV (cont.)

HULL NO. 51 (cont.)

KG = 0 for all angles except 45° and 60°, where KG sin θ = 1". Asterisk indicates Integrator #1 was used; all other readings with Integrator #2.

WL	f(A) Slice	f(A) Total	f(M) Slice	f(M) Total	Tot.f(M) / Tot.f(A)	Total displ.	KZ (in.)
$\theta = 45^\circ$							
Up to 0"	6554	6554	7835	7835	1.1955	661.30	3.3800
0" to 1"	4988	11542	5653	13488	1.1686	1154.59	3.3264
1" to 2"	5804	17346	5142	18630	1.0740	1750.21	3.1381
2" to 3"	5833	23179	3043	21673	.9350	2338.76	2.8624
3" to 5"	9544	32723	1392	23065	.7049	3301.75	2.4033
$\theta = 60^\circ$							
Up to -1"	6496	6496	8741	8741	1.3456	655.45	3.6788
-1" to 1"	9487	15983	11513	20254	1.2672	1612.68	3.5227
1" to 2"	5012	20995	4388	24642	1.1737	2118.40	3.3366
2" to 3"	4826	25821	3038	27680	1.0720	2605.34	3.1341
3" to 5"	8287	34108	2910	30590	.8969	3441.50	2.7855
$\theta = 75^\circ$							
Up to -2"	6570	6570	11914	11914	1.8134	662.91	3.6101
-2" to 0"	8581	15151	13975	25889	1.7087	1528.74	3.4017
0" to 2"	8958	24109	13254	39143	1.6236	2432.60	3.2323
2" to 3"	4260	28369	5620	44763	1.5779	2862.43	3.1431
3" to 4"	3903	32272	4806	49569	1.5360	3256.24	3.0579
$\theta = 90^\circ$							
up to 3"	10250	10250	16361	16361	1.5962	1033.20	3.2144*
3" to 4½"	6404	16654	10095	26456	1.5886	1678.72	3.1991*
4½" to 6"	6419	23073	9945	36401	1.5776	2325.76	3.1770*

HULL NO. 12

KG = 0 for all angles except 38°, where KG sin θ = 2". All readings with integrator #1.

WL	f(A) Slice	f(A) Total	f(M) Slice	f(M) Total	Tot.f(M) / Tot.f(A)	Total displ.	KZ (in.)
$\theta = 7^\circ 51'$							
Up to 1"	4839	4839	3182	3182	.6576	487.77	1.3243
1" to 2"	5519	10358	1351	4533	.4376	1044.09	.8812
2" to 3"	6051	16409	1429	5962	.3633	1654.03	.7316
3" to 4"	6418	22827	1918	7880	.3452	2300.96	.6952
4" to 5"	6914	29741	2537	10417	.3502	2997.89	.7052

TABLE XIV (cont.)

HULL NO. 12 (cont.)

KG = 0 for all angles except 38°, where $KG \sin \theta = 2"$.
All readings with integrator #1.

WL	f(A) Slice	f(A) Total	f(M) Slice	f(M) Total	Tot.f(M) / Tot.f(A)	Total displ.	KZ (in.)
$\theta = 38^\circ$							
Up to 1"	10055	10055	8496	8496	.8450	1013.54	3.7017
1" to 2"	5355	15410	1877	10373	.6731	1553.33	3.3555
2" to 3"	5597	21007	88	10461	.4980	2117.50	3.0029
3" to 4"	5282	26289	-1728	8733	.3322	2649.93	2.6690
4" to 5"	4287	30576	-2785	5948	.1945	3082.06	2.3917
$\theta = 71^\circ 04'$							
Up to 1"	18357	18357	33234	33234	1.7961	1850.38	3.6170
1" to 3"	8108	26634	11286	44520	1.6715	2684.71	3.3661
3" to 4"	3324	29958	3980	48500	1.6189	3019.77	3.2601
1" to -1"	8166	10360	13093	20141	1.9441	1044.29	3.9150
-1" to -2"	3583	6777	6687	13454	1.9852	683.12	3.9978

TABLE XV. RESULTS OF INTEGRATION FOR ZB

HULL NO. 11

KG = 0 for all angles. Integrator #2 used.

θ = 0° (ZB = KB)

WL	f(A) Slice	f(A) Total	f(M) Slice	f(M) Total	Tot.f(M) / Tot.f(A)	Total displ.	ZB (in.)
Up to 1"	3516	3516	995	995	.2830	354.76	.5634
1" to 2"	4494	8010	2961	3956	.4939	808.21	.9832
2" to 3"	4746	12756	5957	9913	.7771	1287.08	1.5470
3" to 4"	5036	17792	8792	18705	1.0513	1795.21	2.0929
4" to 5"	5464	23256	12214	30919	1.3295	2346.53	2.6468
θ = 10°							
Up to 1"	3748	3748	866	866	.2310	378.17	.4599
1" to 2"	4437	8185	3346	4212	.5146	825.87	1.0245
2" to 3"	4863	13048	6075	10287	.7884	1316.54	1.5695
3" to 4"	5165	18213	9043	19330	1.0613	1837.69	2.1128
4" to 5"	5522	23735	12398	31728	1.3368	2394.86	2.6613
θ = 20°							
Up to 1"	4314	4314	614	614	.1423	435.28	.2833
1" to 2"	4459	8773	3339	3953	.4506	885.20	.8970
2" to 3"	5045	13818	6284	10237	.7408	1394.24	1.4748
3" to 4"	5351	19169	9389	19626	1.0238	1934.15	2.0382
4" to 5"	4864	24033	10899	30525	1.2701	2424.93	2.5285
θ = 30°							
Up to 1"	5409	5409	234	234	.0433	545.77	.0862
1" to 2"	4832	10241	3480	3714	.3626	1033.32	.7219
2" to 3"	5438	15679	6886	10600	.6761	1582.01	1.3460
3" to 4"	5113	20792	9064	19664	.9457	2097.91	1.8827
4" to 5"	4107	24899	9160	28824	1.1576	2512.31	2.3046
θ = 45°							
Up to 0"	4121	4121	-1794	-1794	-.4353	415.81	-.8666
0" to 1"	4134	8255	1056	-738	-.0894	832.93	-.1780
1" to 2"	4786	13041	3555	2817	.2160	1315.84	.4300
2" to 3"	4797	17838	5954	8771	.4917	1799.85	.9789
3" to 5"	7531	25369	14705	23476	.9254	2559.73	1.8423
θ = 60°							
Up to -1"	3791	3791	-3589	-3589	-.9467	382.51	-1.8847
-1" to 1"	7718	11509	1230	-3466	-.3012	1161.26	-.5996
1" to 2"	4551	16060	3276	-190	-.0118	1620.45	-.0235
2" to 3"	4109	20169	5109	4919	.2439	2035.05	.4856
3" to 5"	6121	26290	11953	16872	.6418	2652.66	1.2777

TABLE XV (cont.)

HULL NO. 11 (cont.)

KG = 0 for all angles. Integrator #2 used.

WL	f(A) Slice	f(A) Total	f(M) Slice	f(M) Total	Tot.f(M) / Tot.f(A)	Total displ.	ZB (in.)
θ = 75°							
Up to -2"	3880	3880	-7175	-7175	-1.8492	391.49	-3.6814
-2" to 0"	6891	10771	-5512	-10487	-.9736	1086.79	-1.9382
0" to 2"	8359	19130	4177	-6310	-.3298	1930.22	-.6566
2" to 3"	3548	22678	4836	-1474	-.0650	2288.21	-.1294
3" to 4"	2845	25523	4935	3461	.1356	2575.27	.2700

HULL NO. 31

KG = 0 for all angles. Integrator #1 used.

WL	f(A) Slice	f(A) Total	f(M) Slice	f(M) Total	Tot.f(M) / Tot.f(A)	Total displ.	ZB (in.)
θ = 0° (ZB = KB)							
Up to 1"	4390	4390	1149	1149	.2617	442.51	.5270
1" to 2"	5278	9668	3989	5138	.5314	974.53	1.0701
2" to 3"	5397	15065	6759	11897	.7897	1518.55	1.5903
3" to 4"	5495	20560	9820	21717	1.0563	2072.45	2.1272
4" to 5"	5566	26126	13362	35079	1.3427	2633.50	2.7039
θ = 10°							
Up to 1"	4396	4396	938	938	.2134	443.12	.4297
1" to 2"	5049	9445	3814	4752	.5031	952.06	1.0131
2" to 3"	5342	14787	6857	11609	.7851	1490.53	1.5810
3" to 4"	5614	20401	9874	21483	1.0530	2056.42	2.1205
4" to 5"	5808	26209	13538	35021	1.3362	2641.87	2.6908
θ = 20°							
Up to 1"	5209	5209	594	594	.1140	525.07	.2296
1" to 2"	5033	10244	3878	4472	.4365	1032.60	.8790
2" to 3"	5627	15871	7084	11556	.7281	1599.80	1.4662
3" to 4"	6438	22309	10533	22091	.9902	2248.75	1.9941
4" to 5"	5344	27653	12016	34107	1.2334	2787.42	2.4838
θ = 30°							
Up to 1"	6565	6565	-3	-3	-.0004	661.75	-.0008
1" to 2"	5139	11704	4111	4108	.3510	1179.76	.7068
2" to 3"	6022	17726	7598	11706	.6604	1786.78	1.3299
3" to 4"	5675	23401	9809	21515	.9194	2358.82	1.8515
4" to 5"	4504	27905	10090	31605	1.1326	2812.82	2.2808
θ = 45°							
Up to 0"	5378	5378	-2755	-2755	-.5123	542.10	-1.0317
0" to 1"	4453	9831	1178	-1577	-.1604	990.96	-.3230
1" to 2"	5174	15005	3906	2329	.1552	1512.50	.3125
2" to 3"	5081	20086	6449	8778	.4370	2024.67	.8800
3" to 5"	8499	28585	16623	25401	.8886	2881.37	1.7895

TABLE XV (cont.)

HULL NO. 31 (cont.)

KG = 0 for all angles. Integrator #1 used.

WL	f(A) Slice	f(A) Total	f(M) Slice	f(M) Total	Tot.f(M) / Tot.f(A)	Total displ.	ZB (in.)
θ = 60°							
Up to -1"	4861	4861	-4917	-4917	-1.0115	489.99	-2.0370
-1" to 1"	8282	13143	78	-4839	-.3682	1324.81	-.7415
1" to 2"	4641	17784	3481	-1358	-.0764	1792.63	-.1538
2" to 3"	4271	22055	5122	3764	.1707	2223.14	.3438
3" to 5"	7249	29304	14027	17791	.6071	2953.84	1.2226
θ = 75°							
Up to -2"	4899	4899	-7389	-7389	-1.5083	493.82	-3.0374
-2" to 0"	7496	12395	-3767	-11156	-.9000	1249.42	-1.8124
0" to 2"	8541	20936	4273	-6883	-.3288	2110.35	-.6621
2" to 3"	3781	24717	4688	-2195	-.0888	2491.47	-.1788
3" to 4"	3322	28039	5828	3633	.1296	2826.33	.2610

HULL NO. 51

KG = 0 for all angles. Integrator #2 used.

WL	f(A) Slice	f(A) Total	f(M) Slice	f(M) Total	Tot.f(M) / Tot.f(A)	Total displ.	ZB (in.)
θ = 0° (ZB = KB)							
Up to 1"	5343	5343	1340	1340	.2508	539.11	.4993
1" to 2"	6120	11463	4520	5860	.5112	1156.62	1.0177
2" to 3"	6272	17735	7808	13668	.7707	1789.46	1.5345
3" to 4"	6342	24077	11118	24786	1.0294	2429.37	2.0495
4" to 5"	6638	30715	14918	39704	1.2926	3099.14	2.5753
θ = 10°							
Up to 1"	5473	5473	1094	1094	.1999	552.22	.3980
1" to 2"	6101	11574	4504	5598	.4837	1167.82	.9689
2" to 3"	6361	17935	7862	13460	.7505	1809.54	1.4941
3" to 4"	6547	24482	11356	24816	1.0136	2470.23	2.0179
4" to 5"	6814	31296	15228	40044	1.2795	3157.77	2.5472
θ = 20°							
Up to 1"	6263	6263	537	537	..0857	631.94	.1706
1" to 2"	6082	12345	4463	5000	.4050	1245.61	.8063
2" to 3"	6741	19086	8237	13237	.6935	1925.78	1.3806
3" to 4"	6887	25827	11911	25148	.9737	2605.94	1.9384
4" to 5"	6060	31887	13473	38621	1.2112	3217.40	2.4112

TABLE XV (cont.)

HULL NO. 51 (cont.)

KG = 0 for all angles. Integrator #2 used.

WL	f(A) Slice	f(A) Total	f(M) Slice	f(M) Total	Tot.f(M) / Tot.f(A)	Total displ.	ZB (in.)
θ = 30°							
Up to 1"	7698	7698	-246	-246	-.0319	776.73	.0635
1" to 2"	6003	13701	4443	4197	.3063	1382.43	.6098
2" to 3"	7038	20739	8677	12874	.6208	2092.56	1.2359
3" to 4"	6392	27131	11052	23926	.8819	2737.52	1.7757
4" to 5"	5093	32224	11323	35249	1.0939	3251.40	2.1777
θ = 45°							
Up to 0"	5945	5945	-9386	-9386	-1.5788	599.85	-3.1431
0" to 1"	5014	10959	1265	-8121	-.7410	1105.76	-1.4752
1" to 2"	5877	16836	4249	-3872	-.2300	1698.75	-.4579
2" to 3"	5882	22718	7145	3273	.1441	2292.25	.2869
3" to 5"	9612	32330	18628	21901	.6774	3262.10	1.3486
θ = 60°							
Up to -1"	6464	6464	-6482	-6482	-1.0028	652.22	-1.9964
-1" to 1"	9388	15852	34	-6448	-.4068	1599.47	-.8099
1" to 2"	5060	20912	3667	-2781	-.1330	2110.02	-.2648
2" to 3"	4920	25832	6016	3235	.1252	2606.45	.2492
3" to 5"	8348	34180	16284	19519	.5711	3448.76	1.1369
θ = 75°							
Up to -2"	6512	6512	-9595	-9595	-1.4734	657.06	-2.9332
-2" to 0"	8527	15039	-4132	-13727	-.9128	1517.43	-1.8172
0" to 2"	8971	24010	4494	-9233	-.3845	2422.61	-.7655
2" to 3"	4330	28340	5311	-3922	-.1384	2859.50	-.2755
3" to 4"	3998	32338	6891	2969	.0918	3262.90	.1828

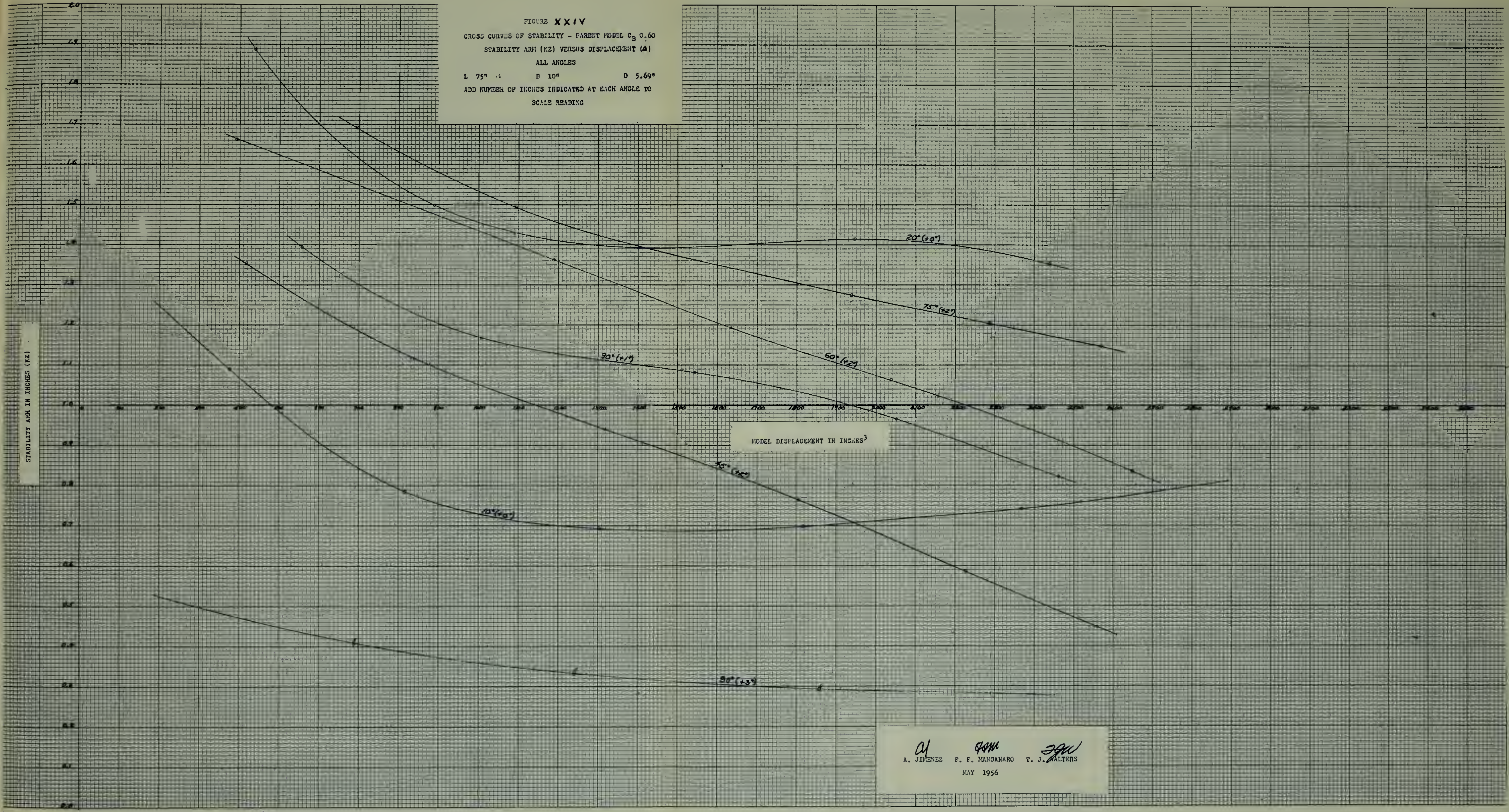

FIGURE XXIV

CROSS CURVES OF STABILITY - PARENT MODEL C_B 0.60

STABILITY ARM (KZ) VERSUS DISPLACEMENT (Δ)

ALL ANGLES

L 75" B 10" D 5.69"

ADD NUMBER OF INCHES INDICATED AT EACH ANGLE TO SCALE READING

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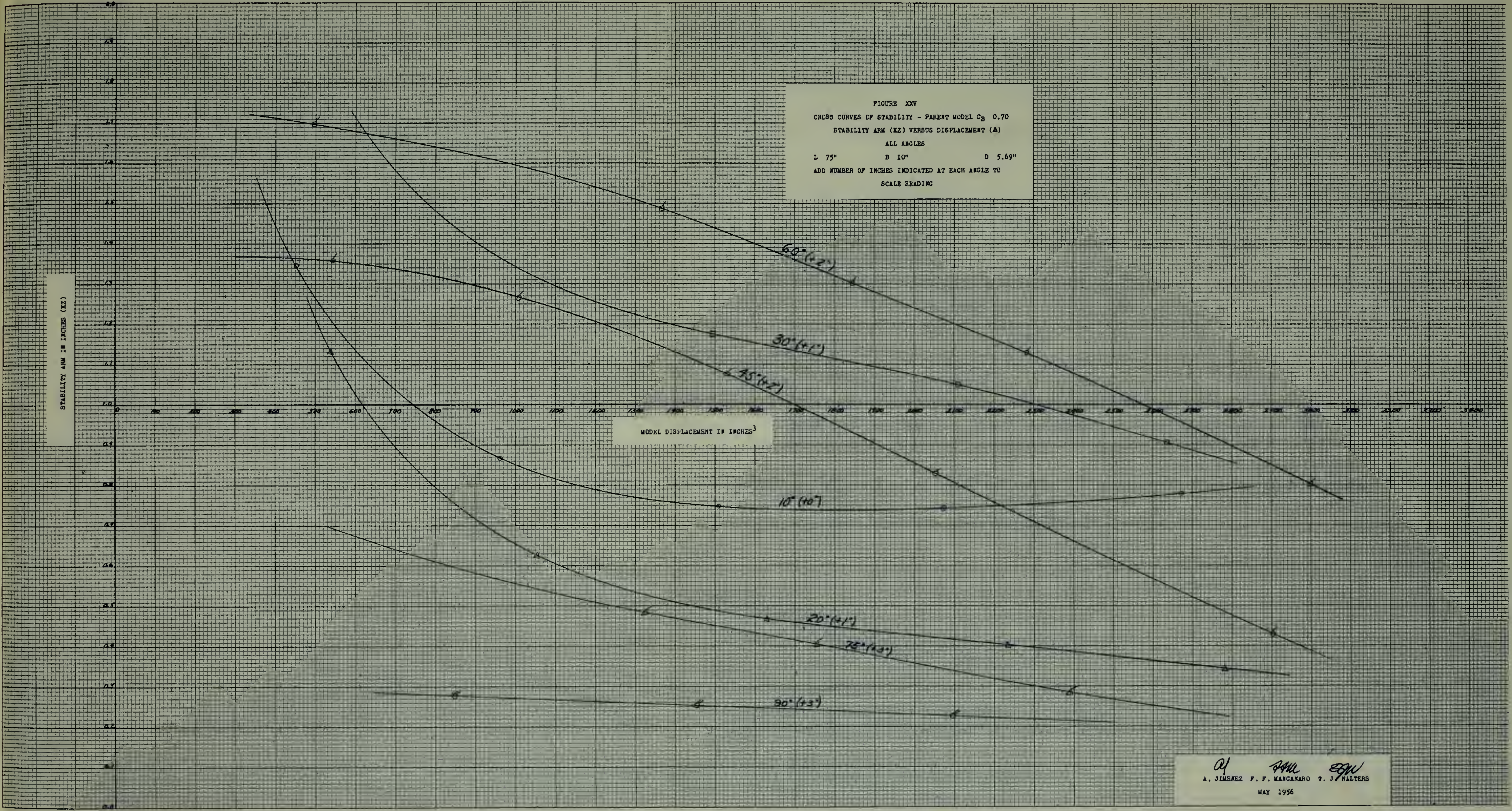

FIGURE XXV

CROSS CURVES OF STABILITY - PARENT MODEL C_B 0.70

STABILITY ARM (KZ) VERSUS DISPLACEMENT (Δ)

ALL ANGLES

L 75" B 10" D 5.69"

ADD NUMBER OF INCHES INDICATED AT EACH ANGLE TO SCALE READING

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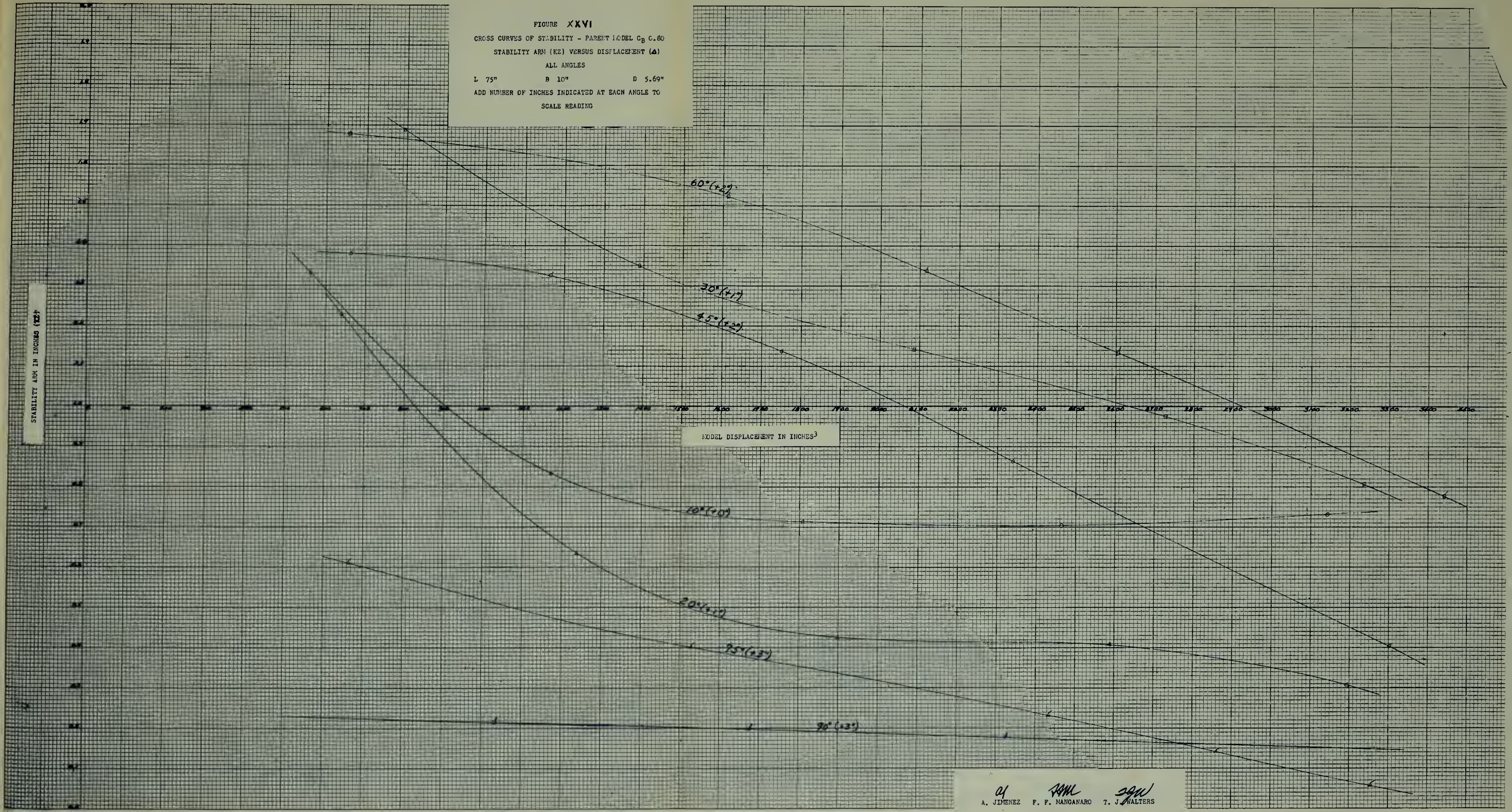
FIGURE XXVI

CROSS CURVES OF STABILITY - PARENT MODEL C_B 0.80

STABILITY ARM (KZ) VERSUS DISPLACEMENT (Δ)

ALL ANGLES

L 75" B 10" D 5.69"

ADD NUMBER OF INCHES INDICATED AT EACH ANGLE TO SCALE READING

A. JIMENEZ F. F. MANGANARO T. J. WALTERS

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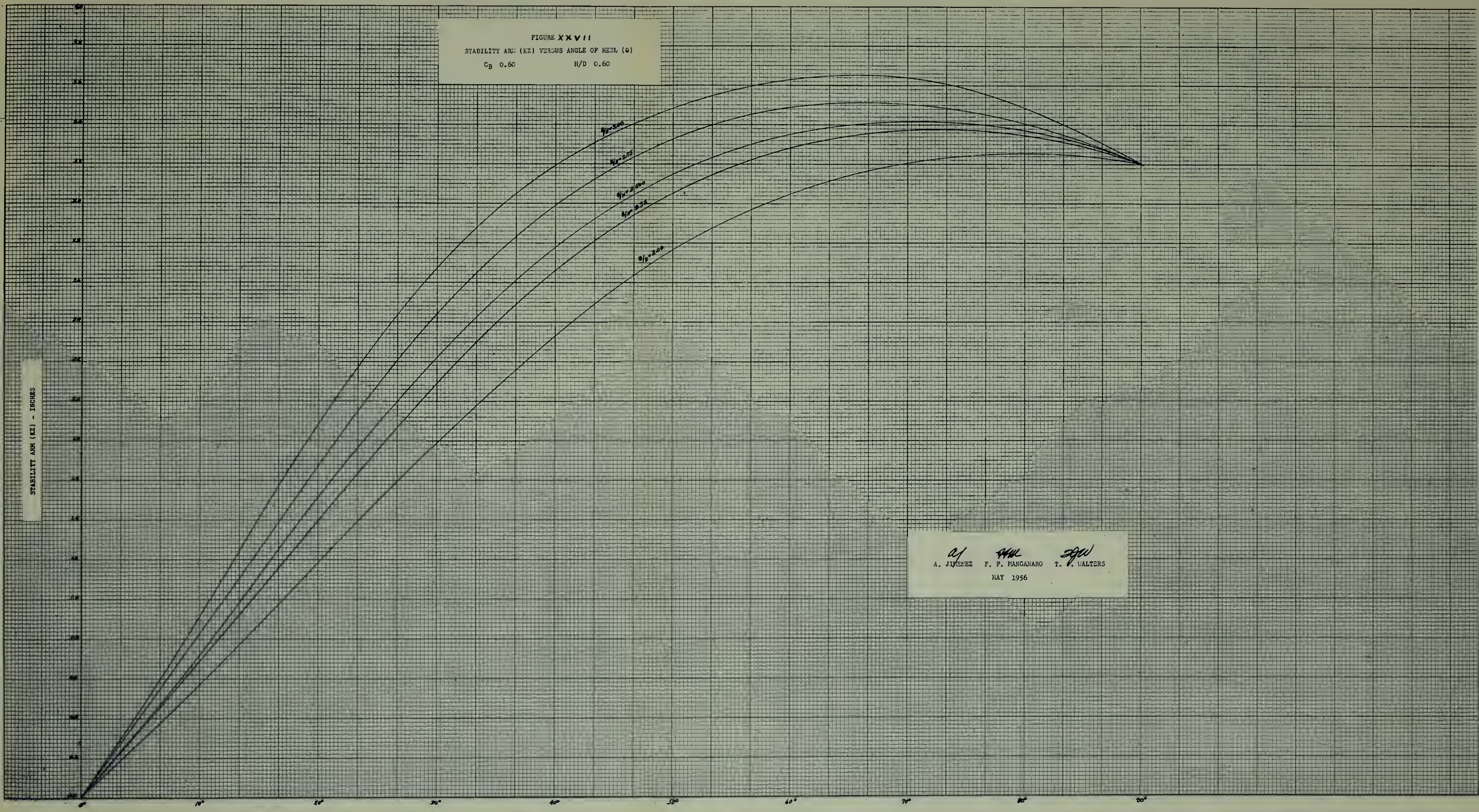
FIGURE XXVII

STABILITY ARM (KZ) VERSUS ANGLE OF HEEL (Φ)

C_B 0.60 H/D 0.60



AJ HFM TJW

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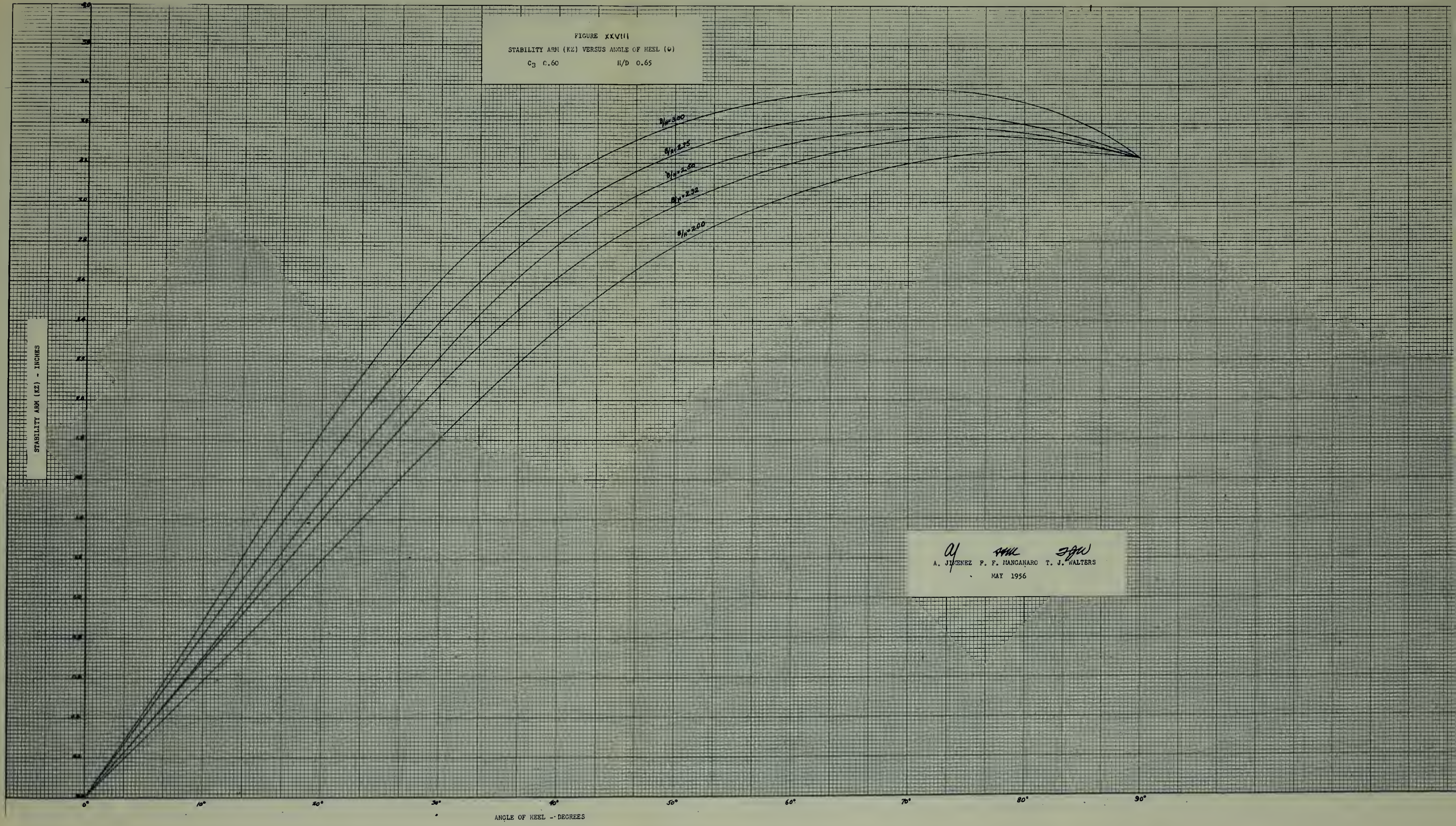

FIGURE XXVIII

STABILITY ARM (KZ) VERSUS ANGLE OF HEEL (Θ)

C_3 0.60 H/D 0.65

AJ ~~~ TJW

A. JIMENEZ P. F. MANGANARO T. J. WALTERS

MAY 1956

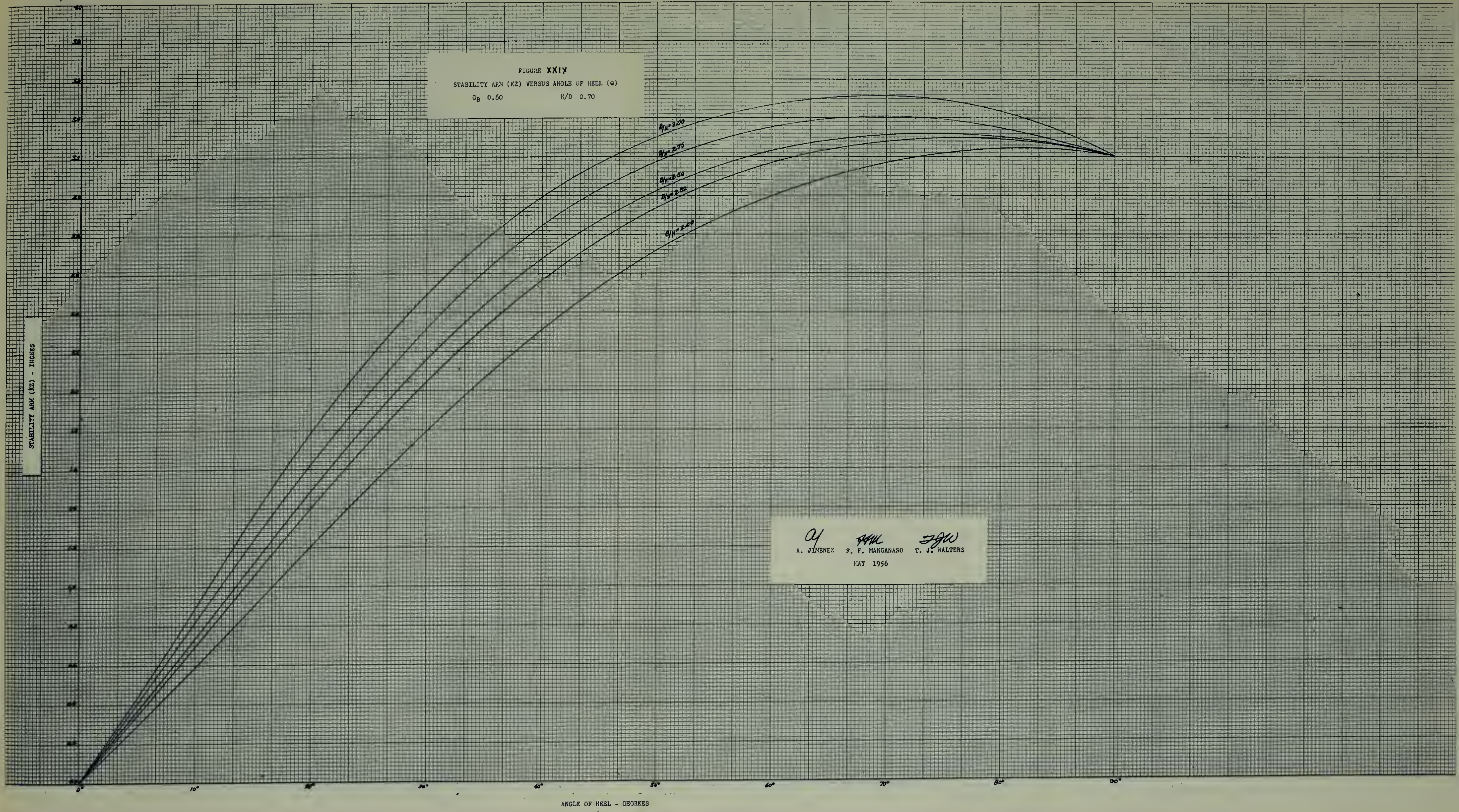

FIGURE XXIX

STABILITY ARM (KZ) VERSUS ANGLE OF HEEL (Θ)

G_B 0.60 H/D 0.70

A. JIMENEZ F. F. MANGANARO T. J. WALTERS

MAY 1956

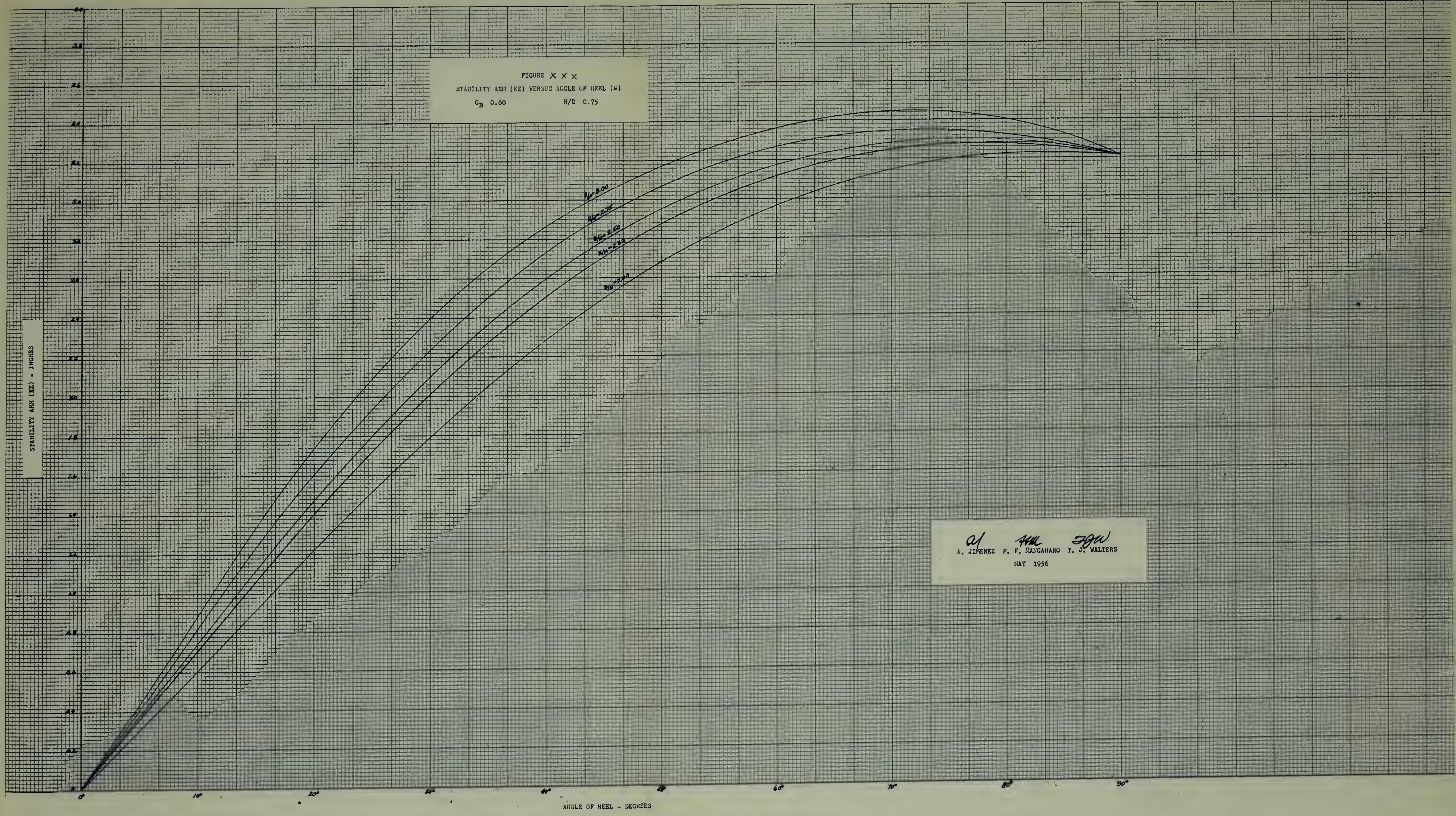

FIGURE XXX

STABILITY ARM (KZ) VERSUS ANGLE OF HEEL (θ)

G_B 0.60　　　H/D 0.75

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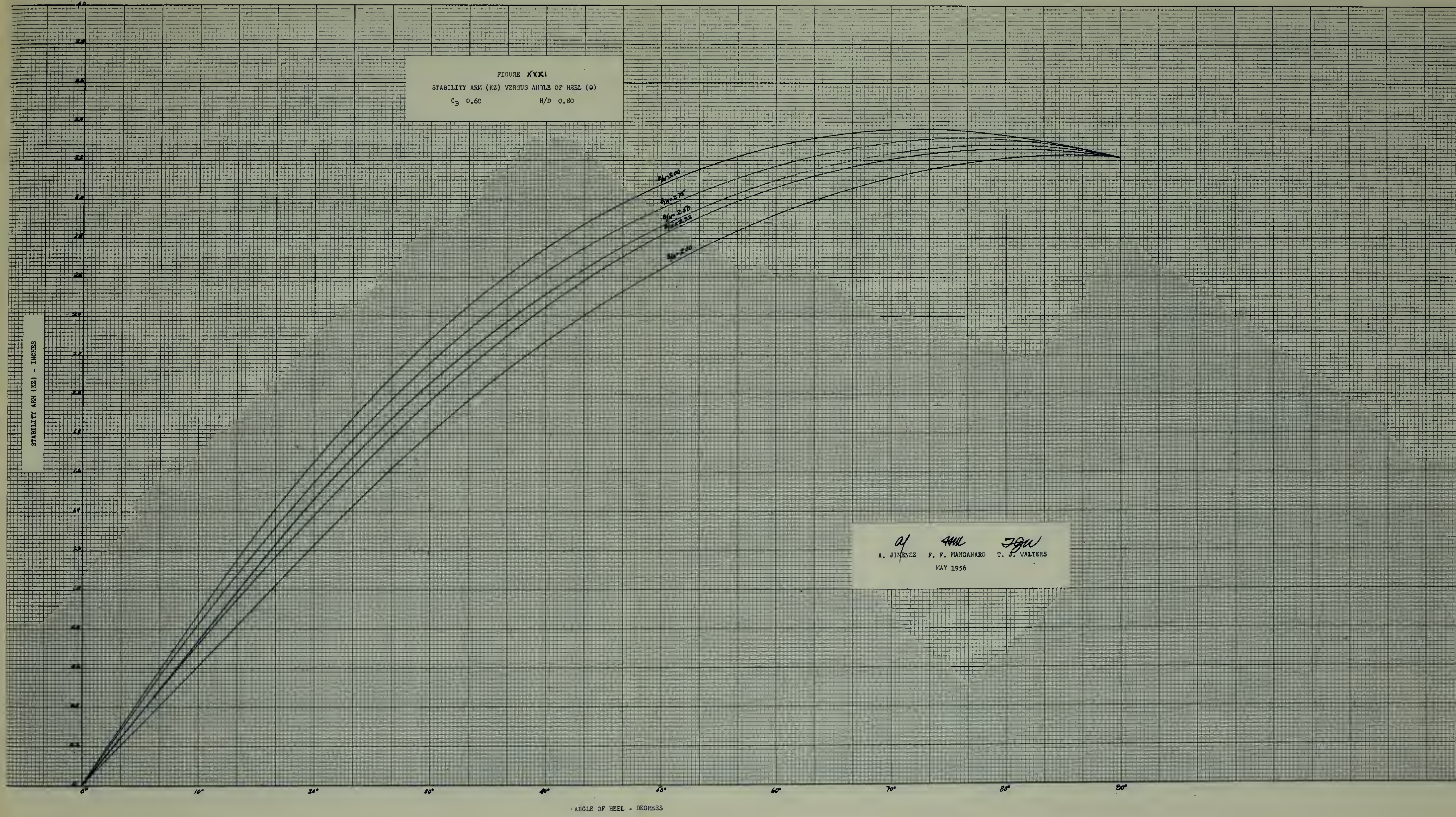

FIGURE XXXI

STABILITY ARM (KZ) VERSUS ANGLE OF HEEL (θ)

C_B 0.60 H/D 0.80

AJ FFM TJW

A. JIMENEZ F. F. MANGANARO T. J. WALTERS

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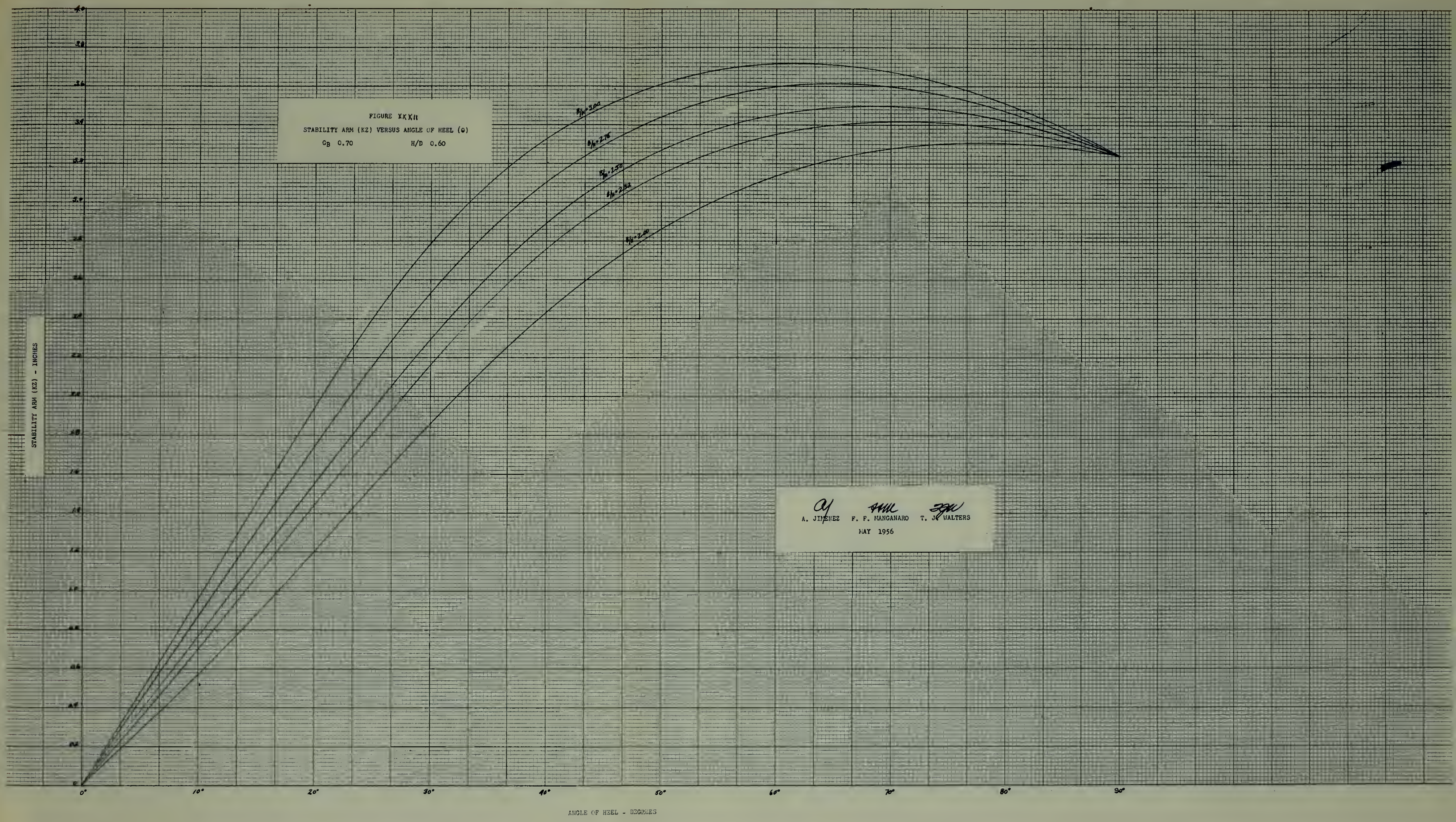

FIGURE XXXII

STABILITY ARM (KZ) VERSUS ANGLE OF HEEL (θ)

G_B 0.70 H/D 0.60

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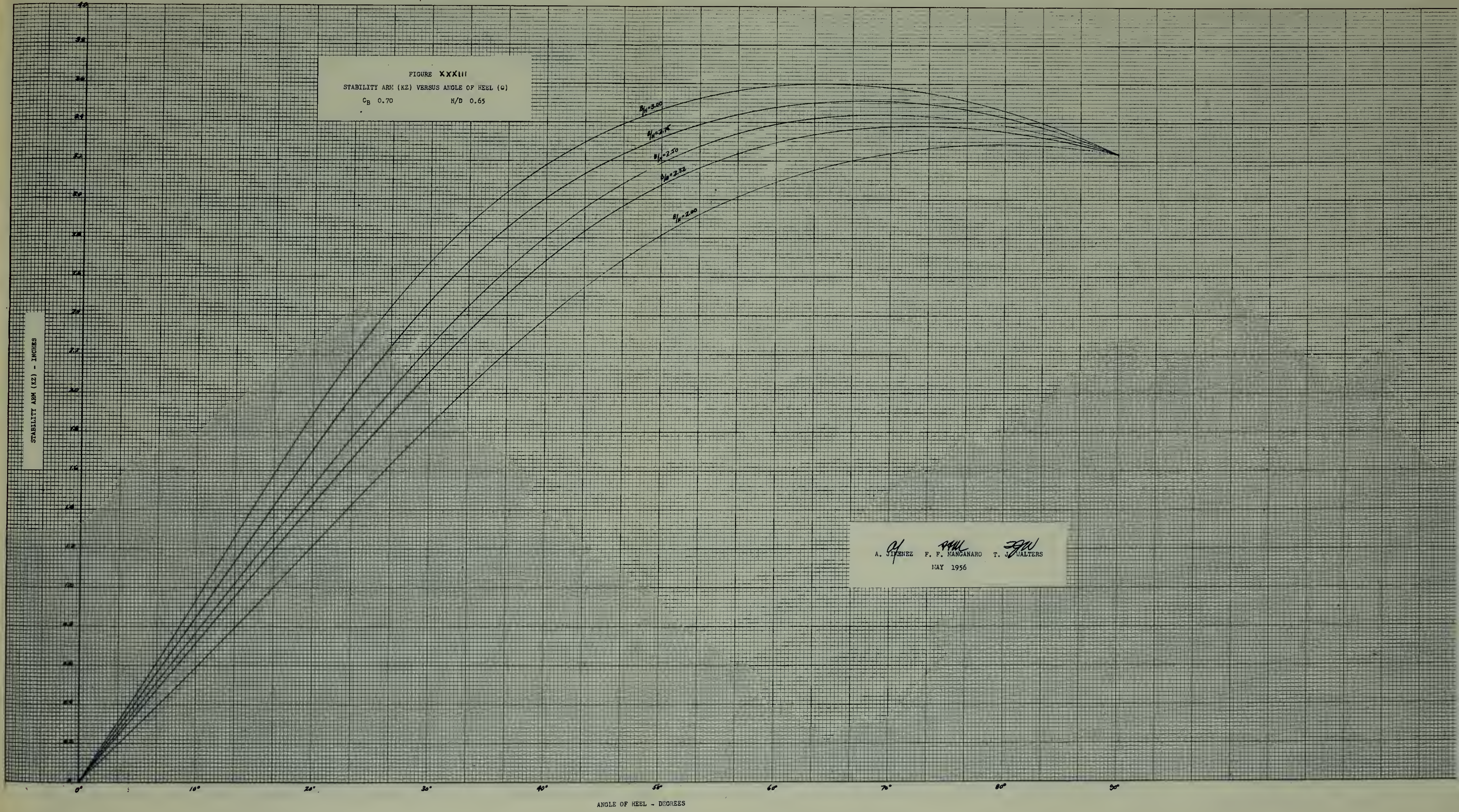

FIGURE XXXIII

STABILITY ARM (KZ) VERSUS ANGLE OF HEEL (Θ)

C_B 0.70 H/D 0.65

A. JIMENEZ F. F. MANGANARO T. J. WALTERS

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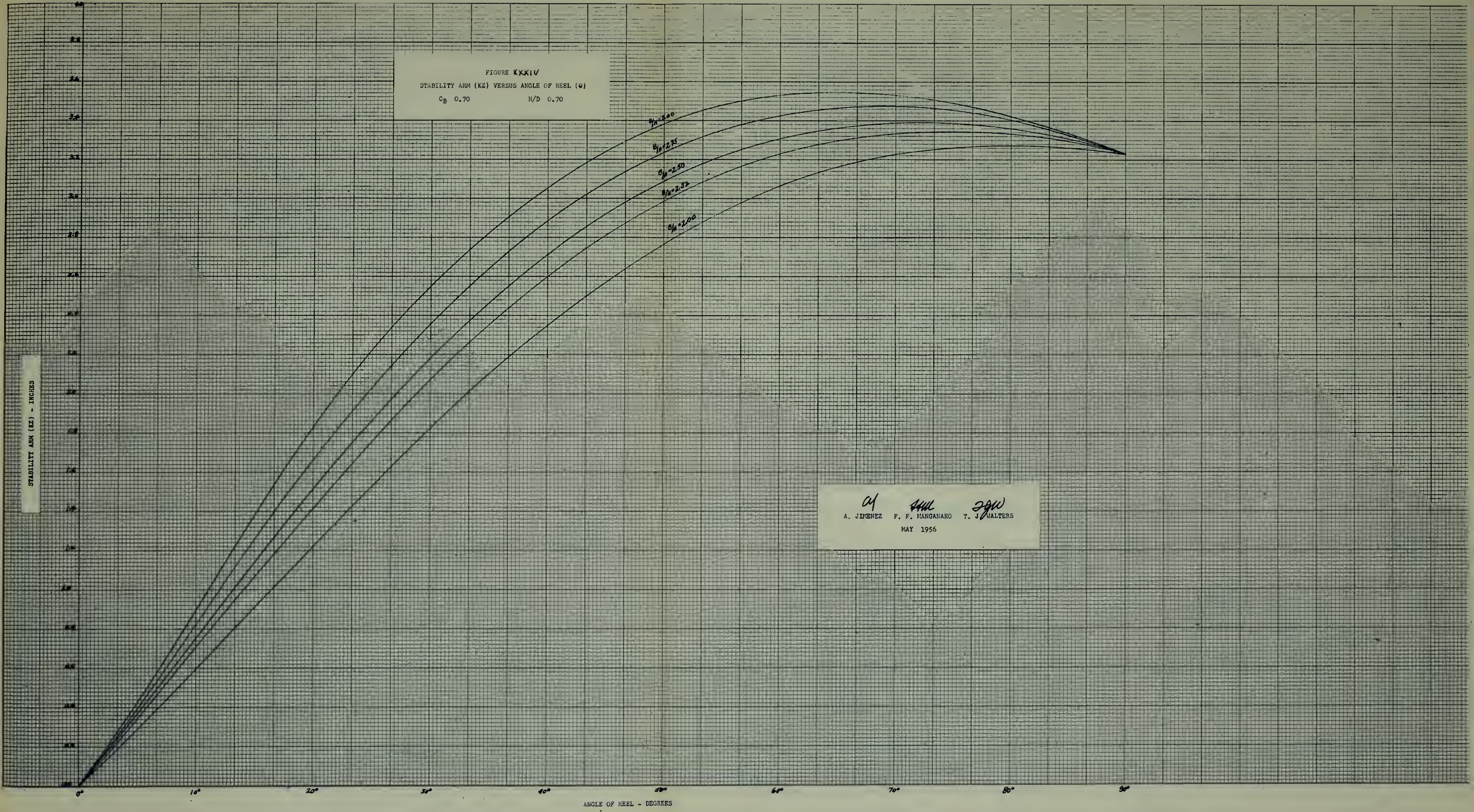

FIGURE XXXIV
STABILITY ARM (KZ) VERSUS ANGLE OF HEEL (θ)
C_B 0.70 H/D 0.70

AJ FFM TJW
A. JIMENEZ F. F. MANGANARO T. J. WALTERS
MAY 1956

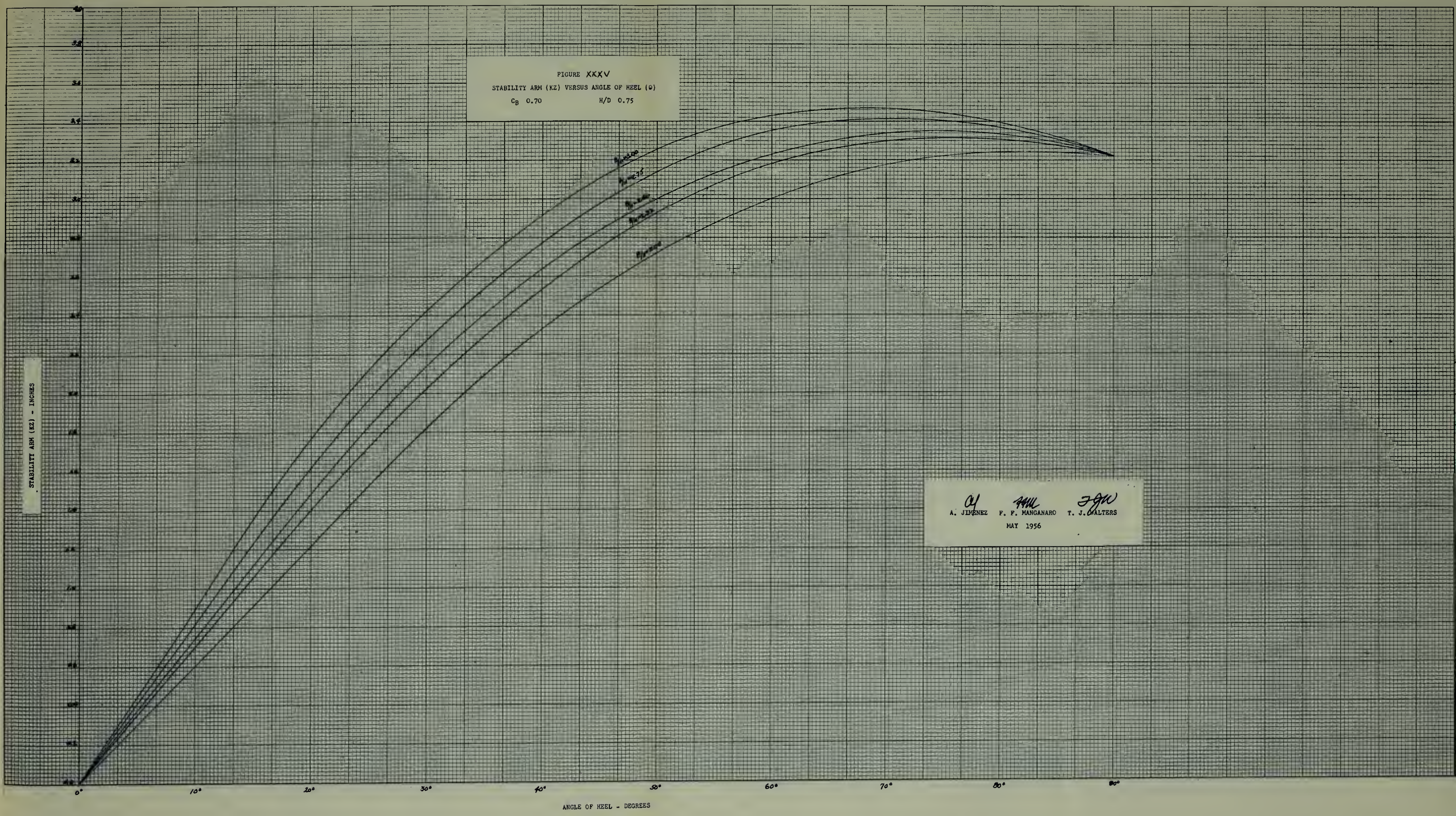
FIGURE XXXV
STABILITY ARM (KZ) VERSUS ANGLE OF HEEL (θ)
C_B 0.70
H/D 0.75
B/H = 3.00
B/H = 2.75
B/H = 2.50
B/H = 2.25
B/H = 2.00
4.0
3.8
3.6
3.4
3.2
3.0
2.8
2.6
2.4
2.2
2.0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
STABILITY ARM (KZ) - INCHES
0°
10°
20°
30°
40°
50°
60°
70°
80°
90°
ANGLE OF HEEL - DEGREES
A. JIMENEZ
F. F. MANGANARO
T. J. WALTERS
MAY 1956

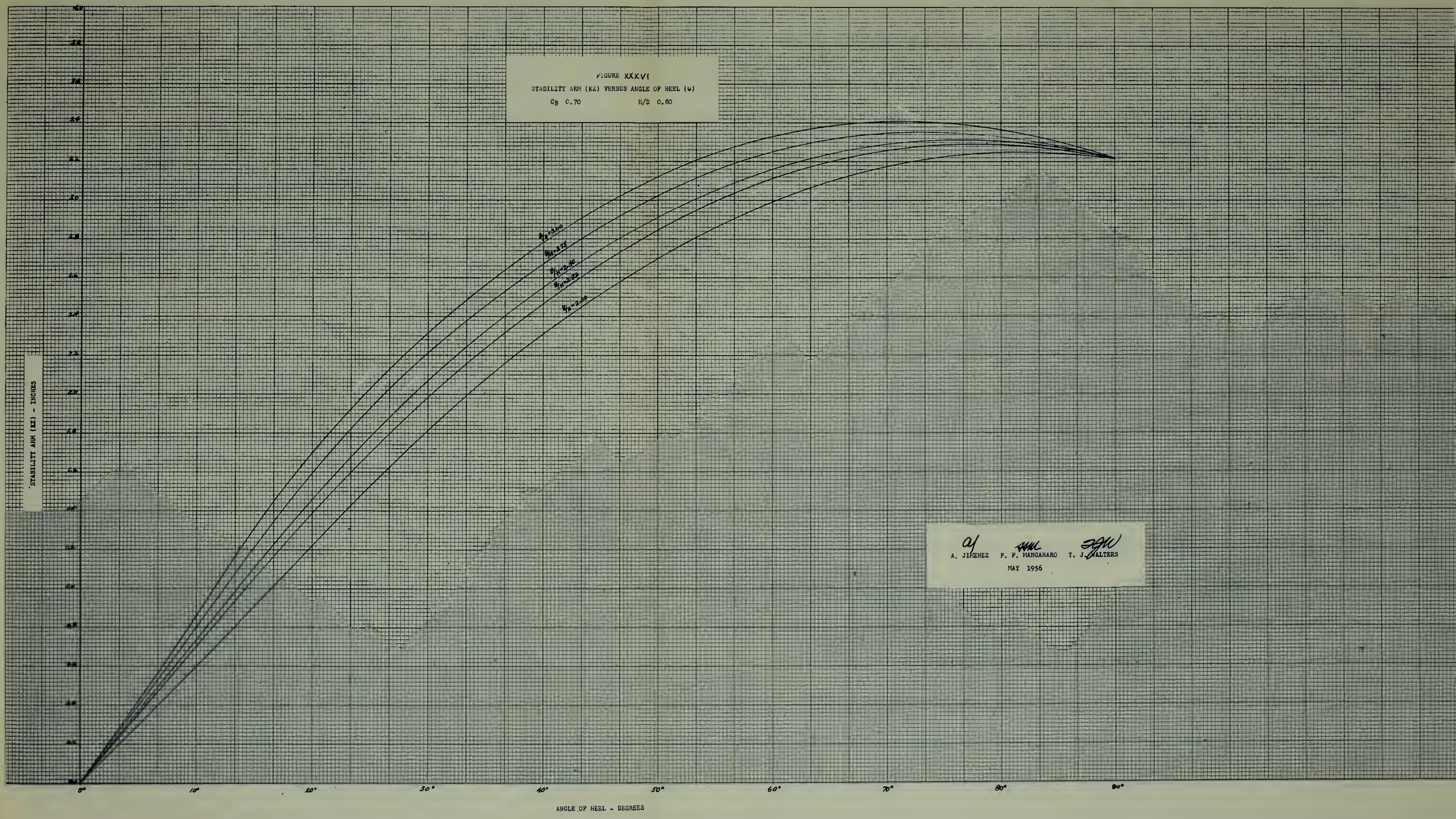

FIGURE XXXVI

STABILITY ARM (KZ) VERSUS ANGLE OF HEEL (ϕ)

C_B 0.70 H/D 0.80

A. JIMENEZ F. F. MANGANARO T. J. WALTERS

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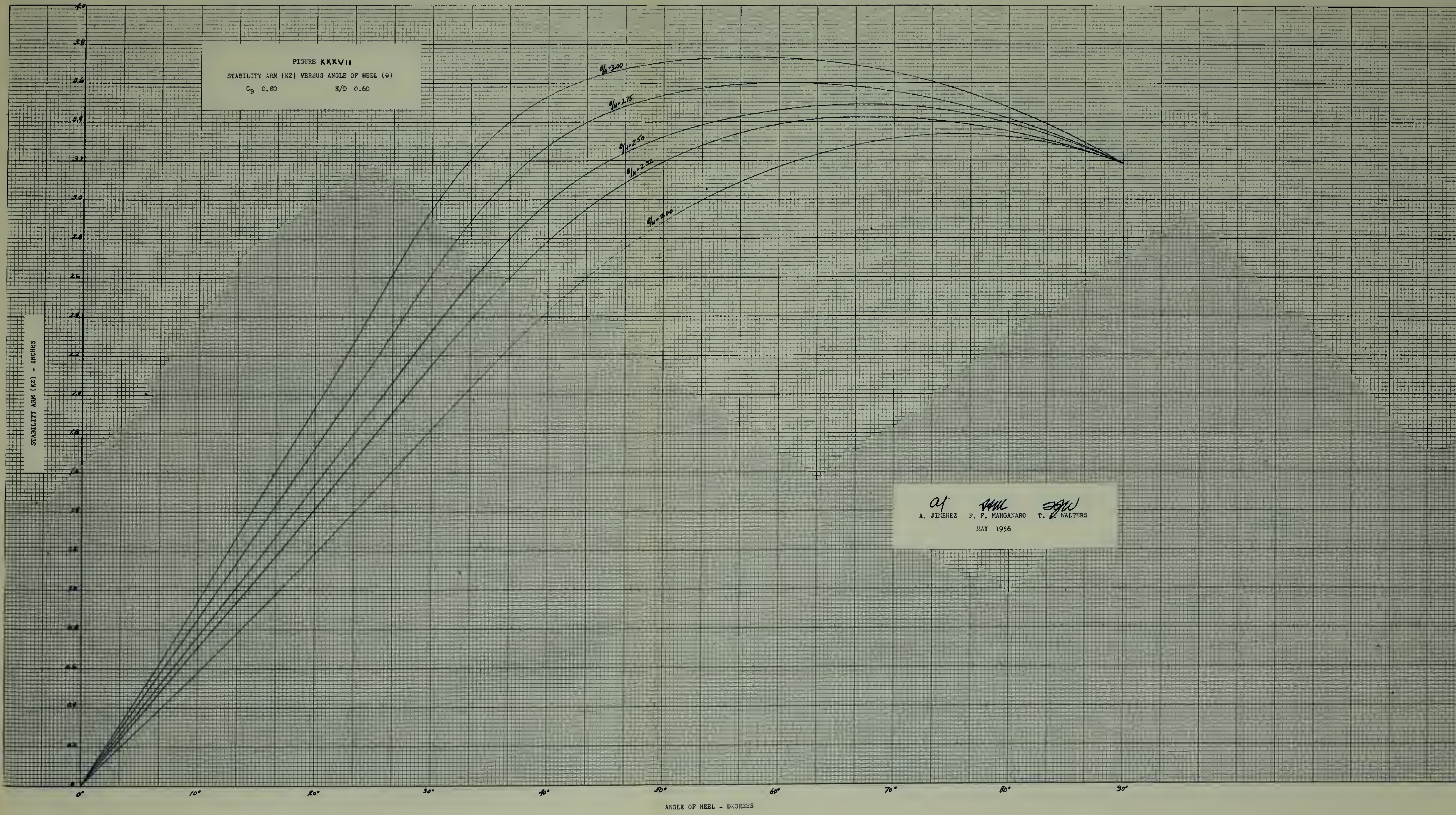
FIGURE XXXVII

STABILITY ARM (KZ) VERSUS ANGLE OF HEEL (Φ)

C_B 0.60   H/D 0.60



A. JIMENEZ   F. F. MANGANARO   T. [illegible] WALTERS

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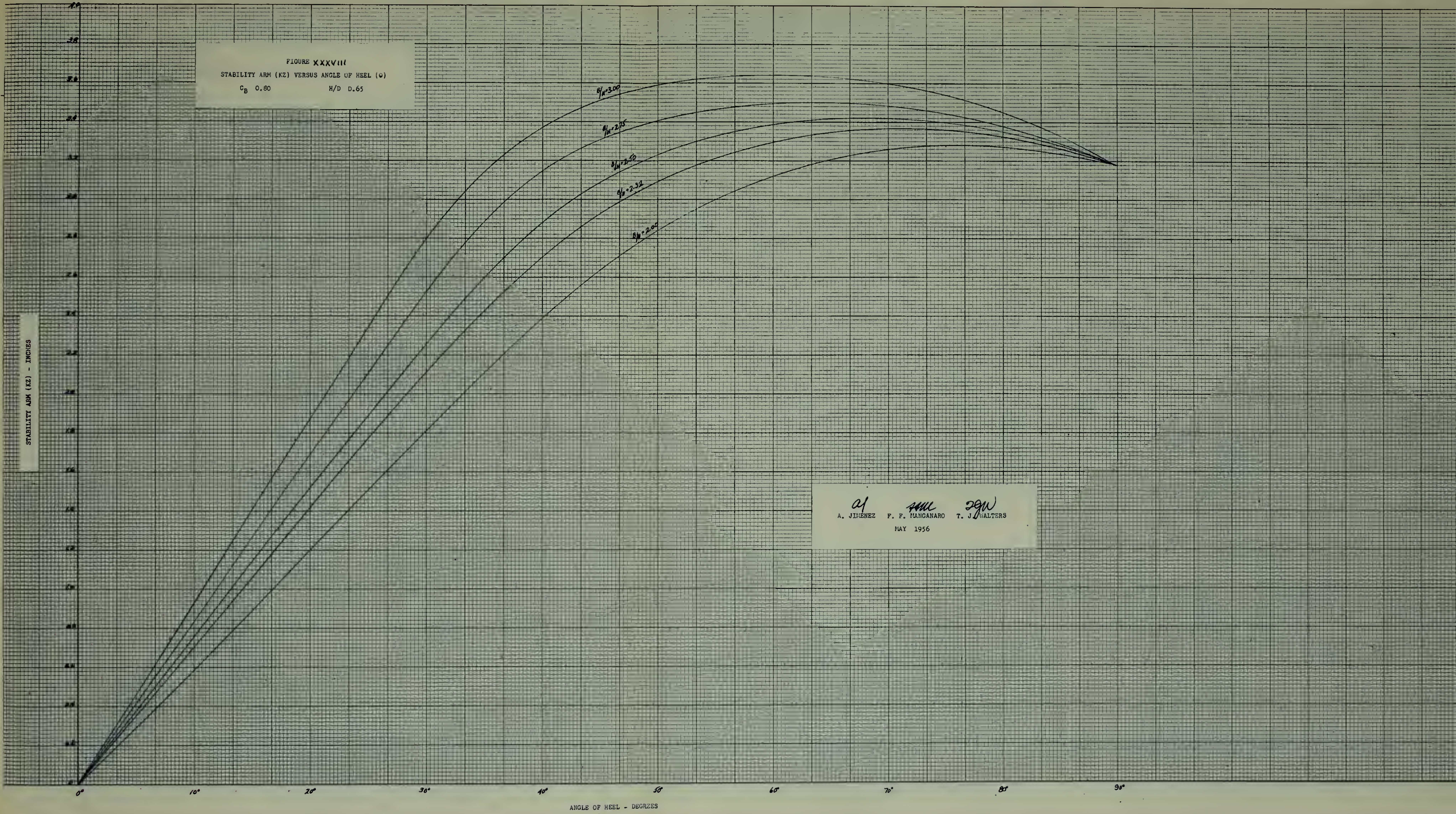

FIGURE XXXVIII
STABILITY ARM (KZ) VERSUS ANGLE OF HEEL (θ)
C_B 0.80 H/D 0.65

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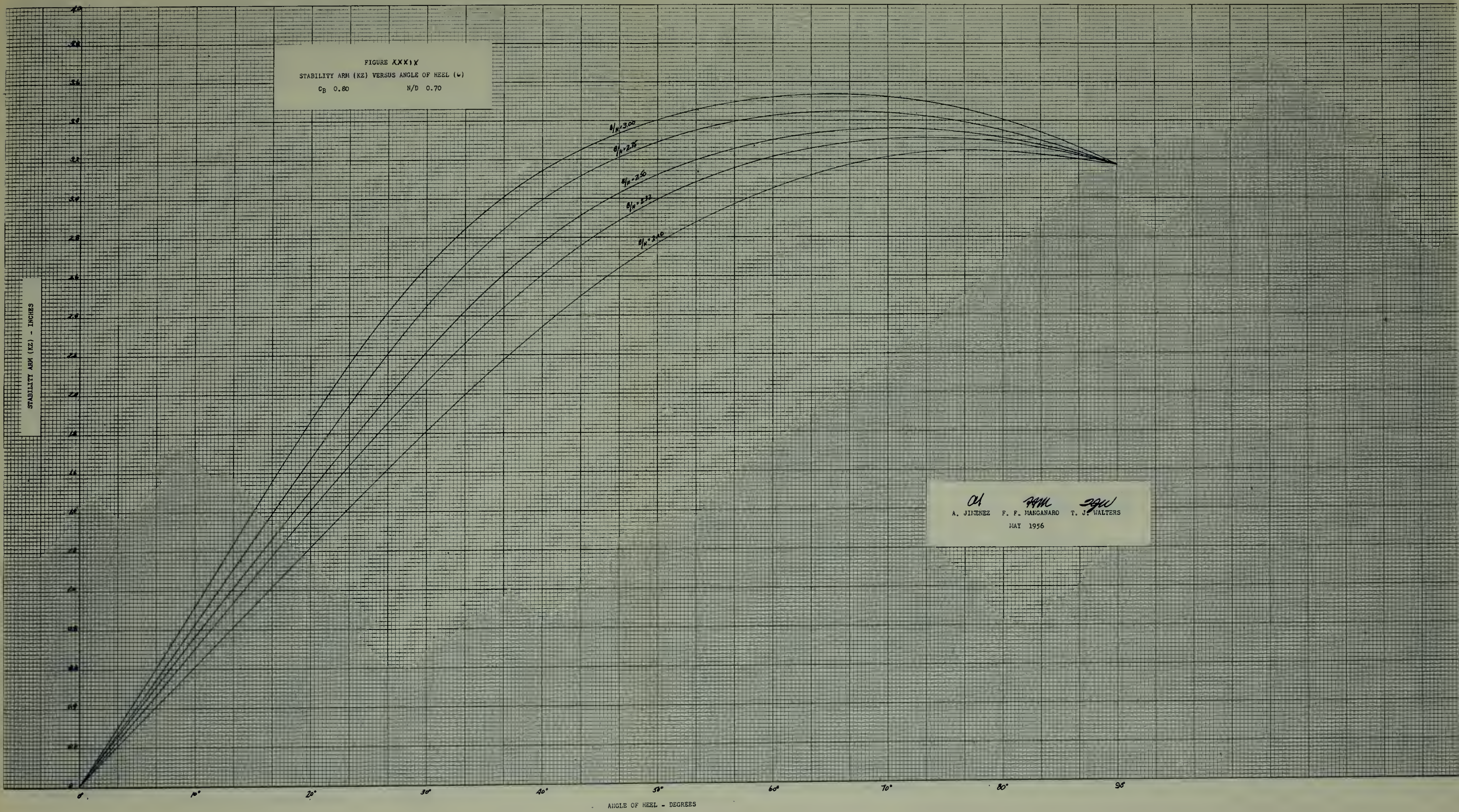

FIGURE XXXIX

STABILITY ARM (KZ) VERSUS ANGLE OF HEEL (φ)

C_B 0.80 N/D 0.70

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MAY 1956

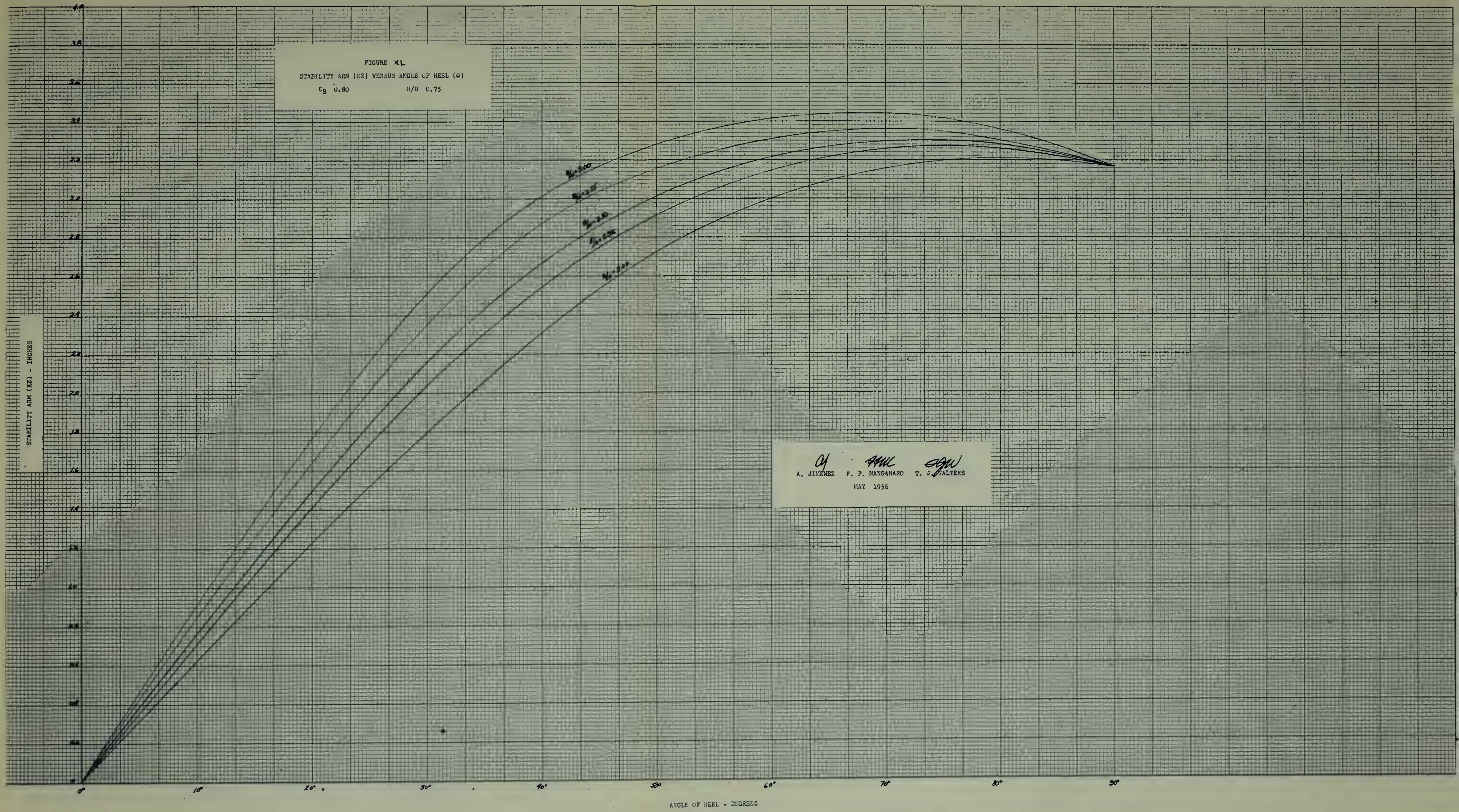

FIGURE XL

STABILITY ARM (KZ) VERSUS ANGLE OF HEEL (Θ)

C_B 0.80　　H/D 0.75

A. JIMENEZ　F. F. MANGANARO　T. J. WALTERS

MAY 1956

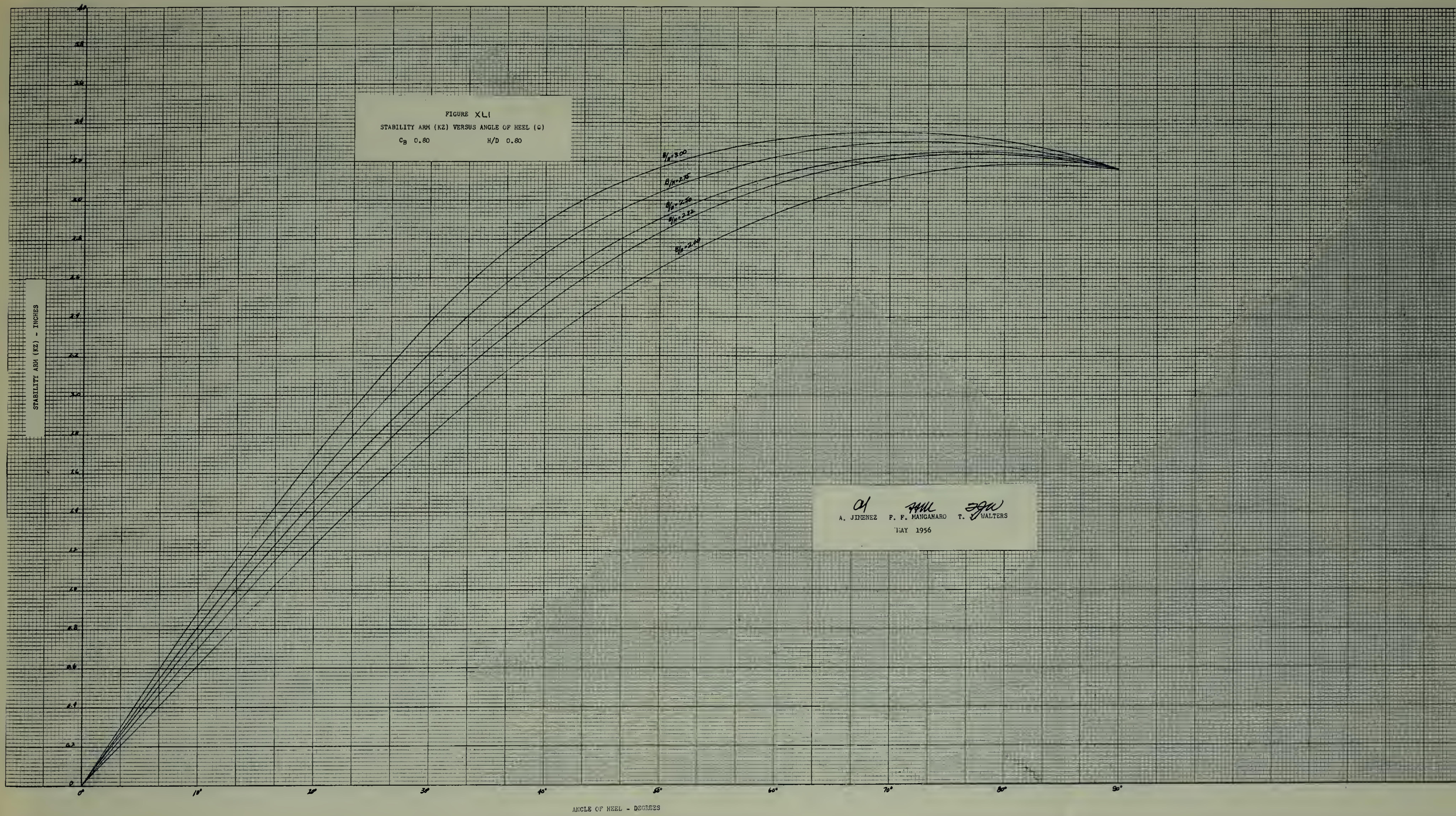

FIGURE XLI

STABILITY ARM (KZ) VERSUS ANGLE OF HEEL (θ)

C_B 0.80 H/D 0.80

A. JIMENEZ F. F. MANGANARO T. WALTERS

MAY 1956

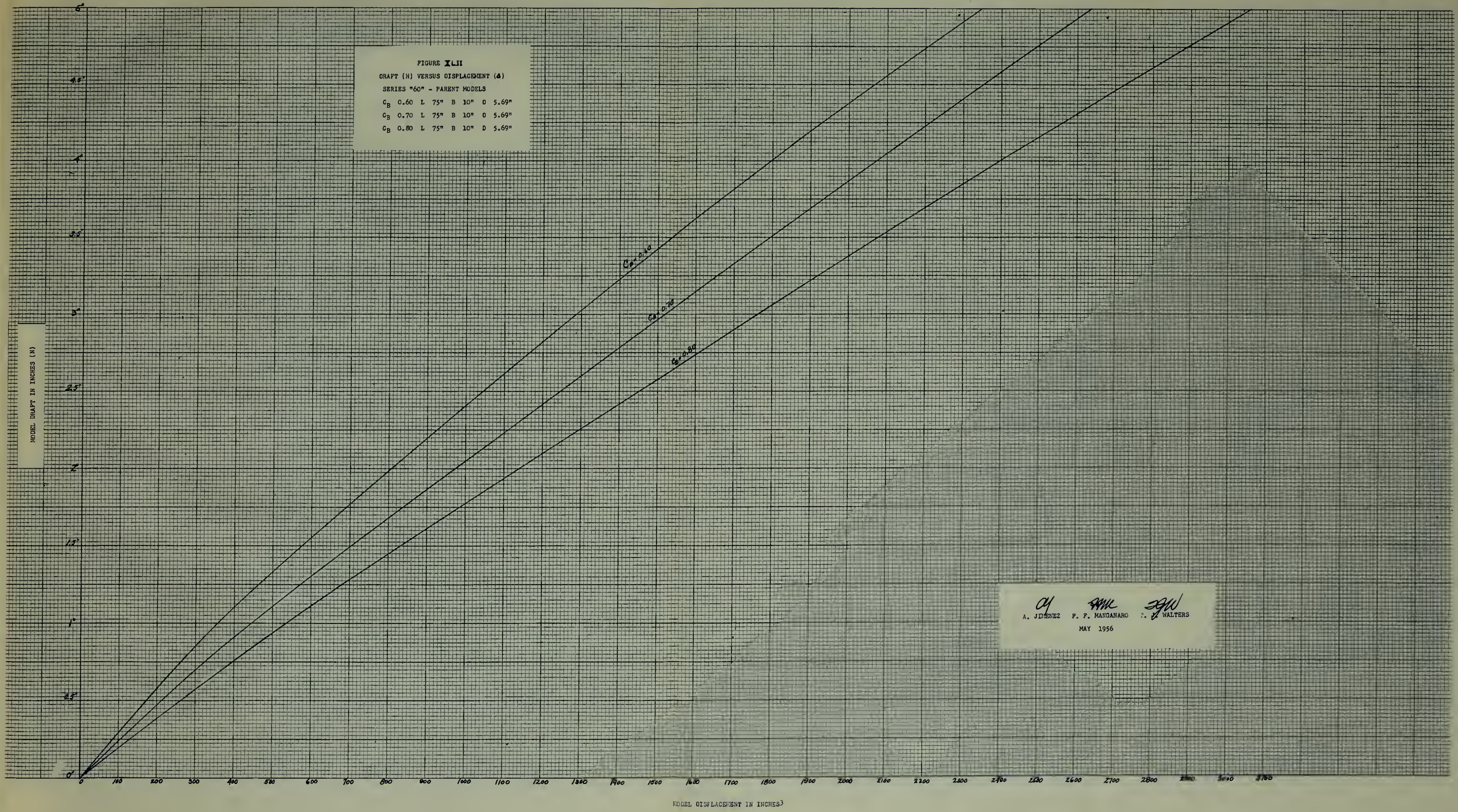

FIGURE XLII

DRAFT (H) VERSUS DISPLACEMENT (Δ)

SERIES "60" - PARENT MODELS

C_B 0.60 L 75" B 10" D 5.69"
C_B 0.70 L 75" B 10" D 5.69"
C_B 0.80 L 75" B 10" D 5.69"

A. JIMENEZ F. F. MANGANARO WALTERS
MAY 1956

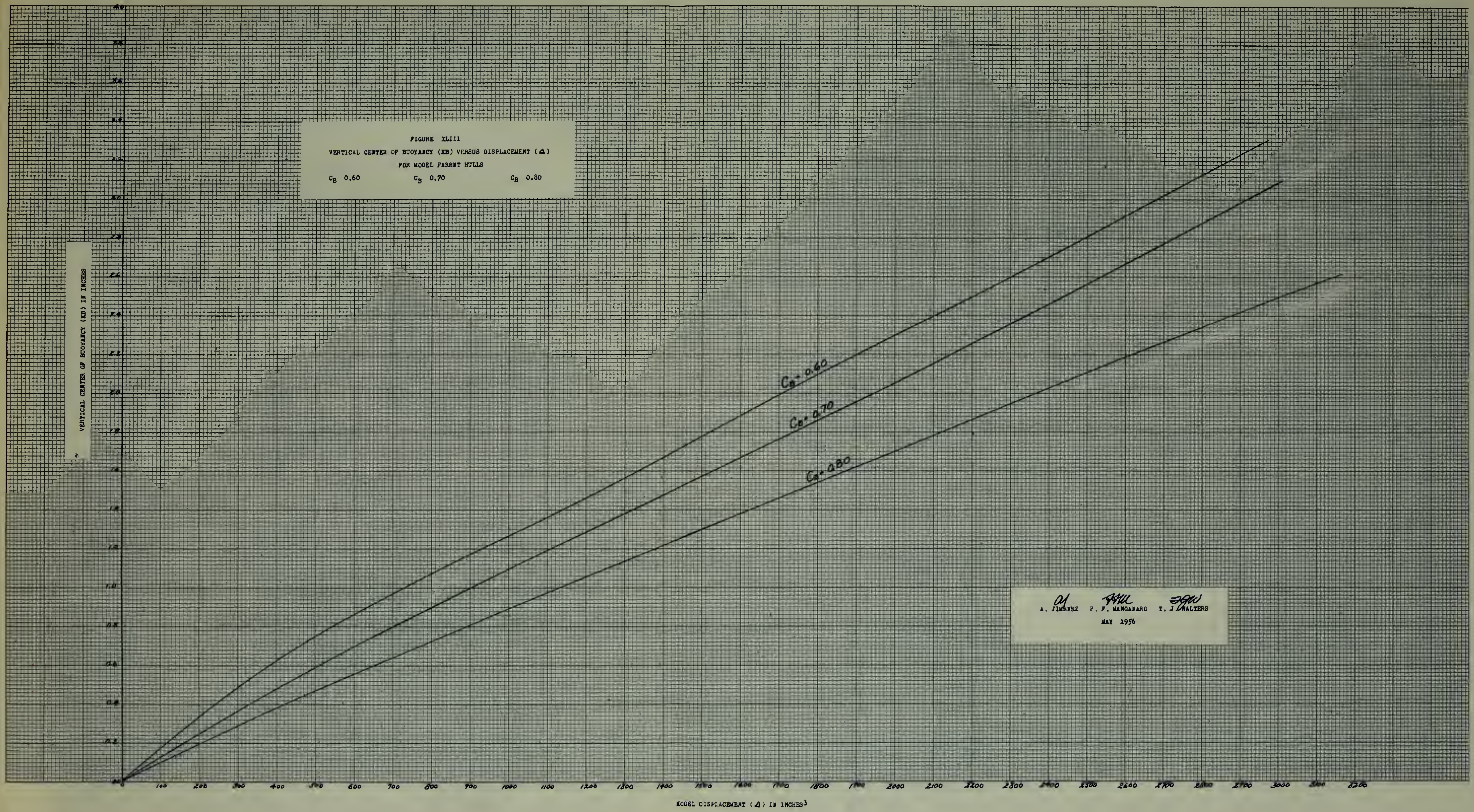

FIGURE XLIII

VERTICAL CENTER OF BUOYANCY (KB) VERSUS DISPLACEMENT (Δ)

FOR MODEL PARENT HULLS

C_B 0.60 C_B 0.70 C_B 0.80

A. JIMENEZ F. P. MANGANARO T. J. WALTERS

MAY 1956

APPENDIX G

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